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ABSTRACTS

This book contains the conference abstracts in two sections: oral presentations and poster presentations, each arranged alphabetically by the name of the first author. The theme and session number can be used to locate the presentation in the main conference program.

ORAL PRESENTATIONS

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Lignocellulosic Biorefinery Concept and Industrial Symbiosis in British Columbia (Theme A 10)

Environmental impacts associated with the use of fossil fuels, uncertainties in future availability of oil, rising energy prices and security issues associated with oil producing states are major reasons driving the consideration for bioenergy and other alternative fuels globally. For Canada, recovering the maximum societal benefit from British Columbia's (BC) 283 million m^3 of mountain pine beetle (MPB) killed timber is an additional driver to develop bioenergy markets. The greatest success in using woody feedstock for energy production is presently achieved with wood and fibre processing residues, which are generally directly combusted for drying lumber and for energy production in pulp and paper mills. A biorefinery facility converts biomass into fuels, materials and chemicals. By generating multiple products, a biorefinery can take advantage of the differences in biomass components, intermediates and varying market demands to maximize the value derived from the feedstock. Bioenergy has great potential to contribute significantly to BC's domestic energy supply, thereby reducing the Province's fossil fuel consumption. Development of a successful biorefining sector will however place new demands on the BC's forest resources and this additional pressure needs to be carefully examined. This study is an analysis of feedstock availability and industrial symbiotic opportunities and it provides essential knowledge for best policy and decision making in BC. It examines the possibility of designing the biorefinery sector in symbiotic relationships with existing mills in BC. Potentially, the cost of producing fuel and products from biorefinery exceeds those from conventional crude oil refineries, excluding environmental costs. Incentives may therefore be required to facilitate the development of the concept under the present market conditions. The paper recommends that more research and development is needed to fully evaluate the costs and benefits of this nascent sector on a life cycle basis.

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Mass Flow Analysis and Technological Innovation in the Manufacture of Solid Wood Products in British Columbia (Theme F 34)

Consumption of forest products is a major source of pressure on forest ecosystems. However, relatively little research has been undertaken to link societal demand for forest products to the challenges confronting the forest industry. Over the last 40 years, British Columbia's forest sector has made substantial progress in substituting knowledge and capital for material input and such developments have had significant impacts on the sector. This paper focuses on the solid wood manufacturing value chain. Technological changes taking place in the solid wood manufacturing industry have led to; (i) increased wood recovery rates, (ii) improved productivity (iii) reduced processing cost (iv) increased automation and mechanization, (v) fewer forest dependent communities. In addition, state of the art sawmills in BC presently produce 34% more lumber from the same roundwood volume than the average sawmill produced 15 years ago, creating the opportunity to use less roundwood to satisfy market demands. Technological developments in the sector may be classified as arising from evolutionary innovations. The paper addresses the impact of such technological developments on sustainable forest management and environmental issues along the supply chain. Tracking flows of materials is fundamental to industrial ecology as it reveals strategic and practical levers for minimizing waste and reducing the exploitation of virgin resources. The study employs the Mass Flow Analysis (MFA) methodology in evaluating the efficiency of wood utilization along the value chain in British Columbia's solid wood processing mills over the last decade, using input-output (I-O) modeling. The results obtained indicate that technological changes within the industry have resulted in higher yields of solid wood products and panels per cubic meter of wood harvested, enabling increased demands for wood and fibre based products to be satisfied by the same harvest volume.

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Evaluation of Industrial Symbiosis through a Business Perspective: A Case Study of the Yorkshire and Humber Region in the UK (Theme E 29)

The evaluation of industrial symbiosis (IS) networks is important for their successful development and proper management. Mirata, Pritchard and Harris (2003) have advocated that conditions have been developed in the UK industrial symbiosis approach that it can be introduced to business strategy. National Industrial Symbiosis Programme (NISP) in the UK also claims to be a business opportunity programme. However, limited empirical evidence is available that supports claims about the alignment of industrial symbiosis concept with the business reality. Mirata, Pritchard and Harris (2003) argue that business environment is receptive of concepts like industrial symbiosis and therefore there is a need to pay attention to the desired attributes of emerging IS networks and how their acquirement can best be facilitated. This paper introduces a new and integrative framework for the evaluation of IS networks from a business perspective. It presents the findings of the evaluation of Yorkshire and Humber region IS network from a business perspective, utilising the above mentioned framework. The Yorkshire and Humber region IS network is part of a recent and important initiative 'NISP' of the UK Government. A case study methodology which utilises multiple data collection techniques such as documentary evidence, observation and in-depth interviews have been used for the study. The outcomes of the research will provide academics and practitioners a new and integrative model to evaluate IS networks from a business perspective. The study will reveal the extent to which IS networks really do offer insights for the businesses to understand the benefits and limitations of symbiotic relationships. It will identify important management and organizational lessons in supporting the longer term performance management systems and structures of IS networks.

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Scenario Analysis of the Future Sustainability of the Supply of Clothing and Textiles to the UK
(Theme D 27)

This paper presents the outcome of a major study on the future supply of clothing and textiles to the UK. The approach was to:• Identify the composition of the sector • Understand current production structures • Identify representative case study products • Develop candidate future scenarios • Complete a triple bottom line analysis for each scenario • Circulate a draft report to stakeholders for feedback. The scenario analysis predicted: • Economic impact through a simplified set of product and National accounts. • Environmental impact through detailed life cycle analyses • Social impact through qualitative description and employment figures. The main findings of the scenario analysis were: • Where production dominates, process efficiencies should be pursued, and the product life extended. • Where raw material production dominates, alternative processes or materials should be used. • Energy requirements for cotton garments are dominated by washing, drying and ironing. • The globalised supply chain does not have significant environmental disadvantage. An ideal consumer would: • Buy second hand clothing and textiles where possible • Buy fewer more durable garments and textile products • Choose new products based on their environmental and social impacts • Lease clothes that would otherwise not be worn to the end of their natural life • Wash clothes less often, at lower temperatures • Extend the life of clothing and textile products through repair • Dispose of used clothing and textiles through recycling services. Strategies to overcome the barriers that inhibit this behaviour include: • Consumer education. • Durability as a component of fashion. • Charging a higher price for a product that lasts twice as long. • Decoupling growth from material flow through services such as repair or ‘fashion upgrades’. • New means to freshen clothes without washing. • New fibre recycling technology.

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Governance as Discourse: Setting Sustainable Energy Targets in New Jersey (Theme D 26)

Is it possible to set meaningful performance targets in a policy domain where responsibility is widely distributed? This paper describes a subnational analytic deliberation—a discourse—on the future of the energy economy of New Jersey, a densely populated U.S. state with few indigenous energy resources. It describes the deliberative process and its associated analytics, and offers a participant's evaluation of the project. From 2006 to 2007, the authors conducted a project to create long-term targets for the performance of New Jersey's energy sector. The target-setting project was organized as a highly participatory, consultative process in which a group of energy analysts supported the deliberations of a group of New Jersey stakeholders. Energy sector experts helped to define the scope of the analytical effort and review its products to ensure that high quality information entered the deliberations. The participatory stakeholder process was designed to bring the targets the legitimacy and acceptance needed to frame political and policy debates. To provide a rigorous framework for long-term projections and tradeoff analysis, the project employed the respected R/Econ econometric model of the New Jersey economy. Using this modeling engine as well as a variety of spreadsheet-level models, analysts evaluated scenarios for New Jersey's future; summarized at www.njssi.org. This project laid political groundwork for New Jersey Executive Order 2007-54 that established aggressive state-level targets for greenhouse gas emissions reductions, and it has added to our understanding of the governance of change in complex sociotechnical systems.

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Application of Material Flow Analysis for Solid Waste and Wastewater Management in Haiphong City, Vietnam (Theme C 23)

The aim of this study is to identify weakness related to solid waste and wastewater management, through quantifying nitrogen and phosphorus flows in urban area of Haiphong city by MFA. The system boundary is defined by the 5 urban districts in Haiphong city, and 8 components are included in the system model developed for nutrient flows in the urban area. Each flow in the model is quantified through literature and interview surveys. Regarding the nitrogen loading to the environment, direct disposal of septage to the environment has the highest contribution, which accounts for 20% of total discharge. Discharges of seepage from septic tank and grey water also have significant portions around 15 % of total discharge. Regarding the phosphorus discharge to the environment, discharge from agricultural activity is the most significant flow, and it accounts for 40% of total phosphorus discharge. Direct disposal of septage to the environment is also significantly contributed to the phosphorus discharge. The main potential to improve nutrients emission is to optimize excreta and wastewater management from households. Fertilizer practice is also important especially for phosphorus control. Through the comparisons with similar studies for other regions, the differences among areas may be caused by not only the regional characteristics, but also assumptions in the estimation of nitrogen flows. Therefore the further research is necessary to improve the accuracy of MFA result. three scenarios for solid waste and wastewater management are developed, then its effect to minimize the nutrient discharge to the environment is quantified.

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The Structure and Evolution of Regional Industrial Ecosystems: Case Studies of Barceloneta and Guayama, Puerto Rico (Theme D 26)

Several disciplines study regional industrial systems to understand how and why groups of firms organize and flourish within specific geographic areas. Economic geographers focus on the factors of production necessary for industry to operate, the growth of agglomeration benefits when many firms congregate and the dynamics of interaction among firms in such systems. By drawing upon the organization of natural ecosystems and the flow of physical resources, industrial ecologists theorize that regional industrial systems could improve their environmental performance and long-term sustainability. This research explores how a framework that combines concepts and tools from both disciplines can be applied to understand patterns in the organization of regional industrial ecosystems. Community structure and evolution are fundamental components of this framework, and are developed through a temporal examination of changing patterns in the natural resource base, and in the abundance, diversity, distribution and interactions of industrial actors. Evolving relationships among the actors, particularly energy and material flows, as depicted in food web analyses, and formal and informal organizational relationships, developed through social network analysis, are elaborated as part of the structure. Industrial symbiosis, or coordinated resource management, is treated as a key inter-firm relationship. The paper details how community structure has evolved over half a century in two industrial ecosystems in Puerto Rico – Barceloneta, a pharmaceutical manufacturing cluster and Guayama, a mixed industry zone – and provides important theoretical and empirical contributions for the study of such systems.

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Measuring Environmental Performance in Regional Industrial Ecosystems – Puerto Rico Case Studies **(Theme E 29)**

Around the world, a few industrial areas have been found to have high levels of resource conservation and recycling through coordinated formal and informal relationships among firms. Through these collaborative efforts, known as industrial symbiosis, the firms in these industrial ecosystems are thought to improve their economic performance, while the regions on the whole benefit through enhanced environmental quality. The island of Puerto Rico industrialized rapidly beginning in the 1950s under a successful program that invited multinational manufacturers to produce goods for export, while generating much needed income for the local population. Significant environmental impacts accompanied the island's growth however, including groundwater contamination, poor air quality and habitat loss in specific locations. Environmental regulations were instituted in the 1970s and many firms strove to meet and exceed these requirements. In two locations – Barceloneta, a pharmaceutical cluster and Guayama, a mixed industrial zone – manufacturing firms chose to work with some of their neighbors in order to reduce their operating costs and environmental impacts. The paper highlights the collaborative efforts in these two ecosystems, including bilateral byproduct exchanges and multilateral utility sharing arrangements. It compares the environmental performance of firms involved in industrial symbiosis initiatives with non-participating firms in order to assess the significance of these efforts. Performance is measured in terms of firms' emissions, material use efficiency and financial savings. The paper separates the effects of internal firm attributes versus collaboration on the performance of the firms, and makes an empirical contribution to hypothesized benefits of eco-industrial activities.

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Data Rectification and Reliability Estimation of Life Cycle Inventories (Theme A 5)

All measured data and models contain errors, and Life Cycle Inventory (LCI) data are no exception, particularly since LCI data are usually collected and combined from diverse sources, which may be unreliable, incomplete or unverifiable. Since the underlying or noise free LCI data must satisfy the laws of conservation, their quality may be improved by imposing these laws on measured data. Such an approach has been popular for improving the quality of or rectifying industrial data. In this presentation, we will describe original research for the rectification and reliability estimation of LCI data. The resulting data are not only more accurate, but also make LCI more reliable for other methods such as energy, exergy, and materials flow analyses. LCI data rectification poses unique challenges that are not encountered in the rectification of industrial data. These include the lack of information about the life cycle network, chemical reactions, and stream compositions, and the fusion of data at multiple scales or different levels of aggregation. Our approach overcomes each of these challenges via a method for multiscale data rectification. This involves solving a constrained optimization problem, where material and energy balance equations form the constraints, combined with statistical hypothesis testing for identifying gross errors or outliers. This approach can utilize knowledge about errors in the available data, or estimate these errors based on reasonable assumptions about their nature. The use of statistical methods also provides estimates of the residual error or reliability of the rectified data. Such information can be used for deciding the focus of future data collection and the accuracy needed in additional data to justify the extra effort or cost. These features of our algorithms are demonstrated via case studies based on data from simulations and from commercial and free LCI databases.

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Toward Integrated Assessment of Technology and Policy Alternatives for Materials Use (Theme D 27)

Successful development and execution of industrial products and processes requires consideration of economic, environmental and social factors that span multiple spatial and temporal scales. For example, engineering decisions are made at a fine scale of individual equipment and process, while its implications are felt at much coarser scales of the economy and ecosystems. In contrast, policies are made at a coarse scale, but its effects are felt at finer scales. Most methods for technology assessment and policy analysis tend to focus on one primary scale. For example, Life Cycle Assessment focuses mainly on the scale of the value chain (supply and demand chains), while Economic Input-Output and General and Partial Equilibrium Models focus on a macroeconomic scale. Most existing research on modeling the relationship between the economy and environment has focused on energy use. The main goals of this talk are to motivate the need for integrated multiscale modeling of economic, industrial and environmental systems, and to discuss potential approaches for satisfying this need. An approach for integrating economic input-output models with engineering process models will be described. Illustrative examples based on this model will demonstrate its use for studying the effect of carbon taxes across scales. An economic input-output (IO) model is used to calculate price changes, and a fundamental model based on thermodynamic conservation laws is utilized for a production plant. The results by the proposed method are compared with those by traditional engineering optimization approaches that ignore price changes in other sectors of the economy. New challenges and areas of further research will be identified, including opportunities for integrating thermodynamic analysis with economic modeling. A general multiscale stochastic modeling framework will be proposed for reaching these goals.

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Hybrid and Thermodynamic Life-Cycle Assessment of Fossil and Biomass-Based Transportation Fuels **(Theme A 4)**

Despite the strong interest and many studies on the environmental implications of transportation fuels, existing studies are not immune to criticisms and call for a more comprehensive study. We present a comprehensive life-cycle analysis (LCA) of bio-based and traditional fuels, i.e., gasoline, corn ethanol, diesel, and biodiesel using input-output hybrid and thermodynamic hybrid models. Most studies have not examined well-to-wheel emissions of biofuels, and have only considered a limited number of pollutants. Furthermore, almost all published studies are process-based life-cycle or thermodynamic analyses, which face the problem of system boundary selection and truncation errors. Our results from input-output hybrid LCA confirm existing insight such as the smaller GHG emissions from the life-cycle of corn ethanol and biodiesel as compared to their petroleum counterparts. We also obtain new insight that the use of corn ethanol and biodiesel as transportation fuels increases emissions of PM10, nitrous oxide, nitrogen oxides (NOx) as well as nutrients such as nitrogen and phosphorous. Also, returns on energy investment (rE) for biofuels are greater than 1 but lower than those of petroleum fuels indicating that extraction and processing of biofuels may be relatively inefficient. Such a distinction has not been illustrated in previous studies. We also apply a thermodynamic hybrid LCA to these fuels based on exergy analysis. This approach focuses primarily on consumption of all types of resources and combines material and energy resources into a single numeraire in a scientifically rigorous manner. This analysis is done at two spatial scales – by considering industrial processes and the supporting ecological processes. Preliminary results indicate that biofuels have relatively low well-to-tank exergetic efficiencies but consume less non-renewable exergy per joule of exergy produced.

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Process Systems Engineering and Supply Chain Management Contributions to IE (Theme F 35)

Industrial ecology (IE) promotes a systems approach to understanding the interactions between industry and the environment. To this end, it draws on a variety of approaches and tools to achieve this objective, including, as examples, dematerialisation, eco-design, product stewardship, material flux analysis (MFA) and life cycle assessment (LCA). An immediate challenge for IE practitioners is to bring these together in a coherent framework as part of sustainability assessment. This is made particularly difficult because of the different temporal and spatial scales embodied within each of these approaches, their poor engagement with dynamic behaviour and uncertainty; and the varying degrees to which they support prospective decision making around multiple objectives. Mature systems research areas, such as process systems engineering (PSE) and supply chain management (SCM) have had to engage with these issues and thus represent a useful resource to facilitate the transition of IE into more rigorous quantitative analysis. While the aims of these research areas differ from each other, and though the boundary of the system can vary, the approaches PSE and SCM use to represent and analyse systems are transferable to any type of industrial system analysis, including IE. PSE and SCM explore the feasibility of systems design and management through simulation and optimisation. Also, both SCM and PSE consider the importance of dynamics and make extensive use of uncertainty analysis to ensure flexibility and robustness of systems. In this paper we outline the possible contribution of PSE and SCM to the research agenda and practice of IE., focusing particularly on simulation and optimisation approaches to the analysis of industrial networks, with due regard to uncertain and dynamic behaviour of individual players within such networks, and of the network as a whole.

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Facilitating Interdisciplinary Research into Industrial Infrastructures (Theme D 26)

Many authors have argued the importance of knowledge integration for modelling complex systems and studying sustainability issues. However, few have described a theoretic framework and method for doing this. In this paper we describe a method for analysing and integrating conceptual models from different scientific disciplines. Our method is a form of conceptual analysis. Its stepwise procedure aims to facilitate interdisciplinary collaboration by (1) uncovering the conceptual convictions of a group of different researchers,(2) creating a comprehensive, coherent analytical model that describes these conceptual convictions, and (3) using this comprehensive model to infer and communicate conceptual differences and similarities between the researchers. The method was applied in the interdisciplinary research programme “Understanding Complex Networks”. The work of several researchers in the field of industrial infrastructures was analysed, resulting in a comprehensive set of generic terms in which the conceptual convictions present in the program could be laid out. The result was presented to all researchers in the programme. They were invited to point out and discuss their own conceptual differences in terms of our model. We expected that this would foster mutual understanding of disciplinary differences, and facilitate discovery of possibilities for knowledge integration. Data-gathering to verify our expectation was still on-going at the time of this writing. Full results will be available at the time of the conference. We expect that our findings will support that: (1) our method can produce a valid comprehensive model that accommodates the world views of researchers with different disciplinary backgrounds, and that (2) such comprehensive models can be used to facilitate knowledge sharing and integration in interdisciplinary projects.

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A Comparative Hybrid LCA of the Economic and Environmental Impacts of Two Oil Sands Extraction Methods **(Theme F 32)**

A wide variety of new technologies are being developed to produce bitumen and other products (refined fuels, electricity, etc.) using surface and in situ techniques for accessing the oil sands bitumen resource in Northern Alberta, Canada. In situ extraction projects are generating an increasing share of oil sands bitumen production. In situ techniques offer lower land use impacts at the operation site and upfront capital costs but require large energy inputs for steam production. Sound decision-making about development of future mining and in situ operations requires improved methods for accounting for the life cycle environmental impacts of the two methods of oil sands production. Applying the life cycle assessment framework to this problem is essential as the upstream and indirect impacts of these two options are non-negligible. We will apply a hybrid life cycle assessment model to investigate the implications of using in situ versus mining technologies for production of bitumen. This hybrid approach will combine the benefits of the process based framework (including process level data specific to oil sands operations in Alberta) and the economy wide Canadian economic input-output LCA model in order to address the economic and environmental impacts of the two scenarios. Note: This abstract focuses on the application of the hybrid model. The discussion of the construction of the model has been submitted as a separate abstract by Alex Charpentier and Heather MacLean from the University of Toronto.

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Industrial Ecology Improves the Understanding of Dynamics in the Future C&D Waste Management System **(Theme A 2)**

The activity in the C&D waste management system is largely determined by the dynamics of the built environment. The dwelling system is the part studied in this work. Due to the inherent dynamics, future waste amounts will increase, the composition will change, and this will pose new challenges to the waste management system, with respect to both capacity and technology. In this work we investigate the future situation for waste management systems, how they can be modeled dynamically, and how systematic use of scenario techniques and dynamic MFA can be combined to produce a basis for sound evaluation of future waste management strategies. A dynamic model for projections of future activity levels will be strongly influenced by the input parameters, in two ways; the historical value of these parameters, and assumptions and scenarios about future levels. Both are important due to the dynamic nature of building systems. Of special importance will be the estimations of lifetime of dwellings, and the size of the dwelling stock demanded by an ever changing population. Future requirements to C&D waste management will change, and there is a strong need for sound and well-founded scenarios about future waste treatment. The scenarios presented in this work will be the result of a systematic process involving experts from C&D related industries and organizations. The scenarios will be considering effects of possible changes in waste treatment policy as well as technical solutions, and the corresponding effects on reuse- and recycling levels. Changing levels of reuse and recycling will in turn have impacts on the materials production, through changes in primary materials demand. Preliminary results suggest large gaps between possible amounts available from the waste management system and the demand for construction materials, even for optimistic scenarios. This is mainly the effect of the dynamics inherent in building systems.

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Combining Dynamic MFA and IO-LCA in Studies of Material and Energy Flows in the Built Environment **(Theme A 4)**

The focus of this work is to develop a methodology for integrating dynamic MFA methodology with Input/Output-LCA methodology in order to evaluate the environmental performance and implications of large and complex systems. The C&D industry is an important sector in terms of economy, and in terms of waste generation and materials consumption. Activities related to materials production, building construction, use of the building during its lifetime, demolition and waste treatment of materials all have significant repercussions in the rest of the economy, as they are dependent on a variety of commodities and services provided by other economic sectors. The value of IO-LCA is the ability to include all the induced activity in the remaining economy, caused by the demand for C&D services. In this work, we focus on the part of the built environment comprised by the dwelling stock. The built environment is a highly dynamic system, and calls for a dynamic MFA model to describe and explain its behavior. A dynamic MFA will provide the necessary information about the flows within the dwelling system, with respect to construction, renovation and demolition activity, as well as the stock in use. This information represents the information to an IO-model describing the necessary commodities and services needed to fulfill the demand for C&D related activities. Experiences from the approach to combine the two methodologies will be discussed with respect to data availability, interpretation of results and general strengths and weaknesses. Furthermore, we want to address the contribution to the understanding of the overall C&D system, from raw materials extraction to final waste treatment. Results from an evaluation of the Norwegian dwelling system will be presented and discussed, with respect to materials and energy flows of both the direct C&D activities and of the induced activities in the remaining economy.

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Smart Labels for Waste-Resource Management: an Integrated Assessment (Theme D 27)

This contribution explores the potential of RFID (Radio Frequency Identification) for improving the current waste and resource management system in Switzerland. It presents the following three possible options for utilizing RFID tags to support waste management processes; “at source automation”, “end of pipe I” (combination of the current system with an additional separation of recyclables before incineration) and “end of pipe II” (replacement of the current recycling infrastructure by sorting at the incineration plant),. These options tackle the waste and resource management chain at different processes, i.e. waste generation, waste separation and treatment. Based on a MFA (Material Flow Analysis), we performed a multicriteria assessment of these options with experts of the waste management sector. The expert assessment for batteries and electrical appliances for the proposed options showed that from an ecological perspective the implementation of RFID in waste management would be desirable and would lead to an improvement of the current recycling rate in Switzerland for the goods studied. From an economic perspective new investments would be required in the range of 1 to 5 times the maintenance costs of the current separate collection system. From a social perspective, the utilization of RFID tags in the waste management process was ambiguous. In particular the end of pipe II scenario would on the one hand, significantly improve the convenience of consumers. On the other hand, experts see privacy and moreover, social responsibility as being in thread. The experts considered the ecological and social aspects to be more relevant than the economic ones. Thus, they preferred the “end of pipe I” option over the other options and the status quo.

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Eco-efficiency evaluation of industrial system in China: an extension data envelopment analysis approach **(Theme C 21)**

Any economic activity involves using the natural environment. At the same time the principle of sustainable development requires to deal with nature as carefully as possible. Therefore it is important to measure how and to which extent nature is used by economy over time. Eco-efficiency is a measurement developed to measure the economic performance of the national economy, which takes into account environmental aspects as well. This paper addresses the eco-efficiency evaluation problem for region industrial system in China. A DEA-based non-radial model is developed, including undesirable outputs. Using real data of 30 provinces, an empirical study is employed to illustrate the impacts of undesirable outputs on DMUs' eco-efficiencies. The results show only Taijing, Shanghai, Guangdong, Beijing, Hainan and Qinghai are ecological efficient. Based on different models, the efficient units are efficient, not depending on the model used. The results also show the province with higher level GDP per capital will have higher eco-efficiency and provinces at east will more ecological efficient than west. The results will gain deeper insights into the causes of eco-inefficiency, and give further supports on environmental protection policy in China.

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A Multi-agent Based Model of the Stability of Industrial Symbiosis (Theme D 26)

Industrial symbiosis, core part of the industrial ecology, targets higher resource efficiency by identifying and implementing synergies and linkages between different industries that will lead previously unwanted or low value output resources to become useful and competitively priced inputs for others. Industrial symbiosis portrays great advantage in promoting the economic efficiency, cutting down the cost of natural resources and protecting local environment. However, industrial symbiosis network is still less complicated than natural ecosystem. Slight change of a node or company within that network may significantly influence the function of industrial symbiosis networks. This paper chooses Longsheng industrial symbiosis program in Zhejiang province as a case study. First, it examines the structure, function and linkages of the industrial symbiosis in Longsheng industrial symbiosis. Secondly, a multi-agent based decision-making model is established, among which enterprises are considered to be agents and they are connected with each other via material and value flows. Each agent has an auto decision-making mechanism based on its costs and benefits. Finally, impact analysis of the network is conducted under the disturbances such as technique advancement, production alteration and other factors. A dynamic decision-making process is simulated and the stability of industrial symbiosis is evaluated according to two indicators, that is, the rate of enterprise exit and the possibility of industrial symbiosis breakdown.

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Combining Scenario Methods and LCA in Strategic Environmental Assessment – a Case of Municipal Energy Planning in Sweden (Theme D 27)

Strategic plans at the national, regional or local level may have significant impact on the environment. It has been recognised that assessing impacts early in the decision-making process before the adoption of plans and programs, may play a key role in sustainable development. An EU Directive with this specific purpose (2001/42/EC) was implemented in the member states in 2004. The tool for such assessments is Strategic Environmental Assessment (SEA). SEA is a procedural tool, prescribing what should be done, rather than how. From the field of industrial ecology, there are a multitude of tools available that, at least in theory, can be integrated in the SEA process. This was illustrated in a framework for SEA in the energy sector, proposed by Finnveden et al. (2003). Our hypothesis is that better practice for SEA can be achieved through the application of existing tools for scenarios, deliberation, and environmental assessment. In an applied research project, researchers cooperated with local authorities in a small Swedish municipality, which was about to develop a new municipal energy plan. This paper focuses on two key components of SEA explored in the project; identification of alternatives with scenario techniques and environmental assessment with Life Cycle Assessment (LCA). Our main aims were: – To explore the use of visionary and external scenarios as means to improve the chances of reaching the planning objectives. – To test the usefulness of LCA as a tool for environmental impact prediction in SEA. – To explore how scenario techniques and LCA can be combined, something which has rarely been done. In this article we will discuss this approach with regard to feasibility, applicability to SEA in general, the challenge of combining scenario methods and LCA, suggested improvements, and applicability in other planning contexts.

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MFA as a Tool in Policymaking Processes - Experience from the Revision of Norway's "National Action Plan for Construction and Demolition Waste". (Theme A 13)

In this paper we describe how MFA and other scientific based information were used actively in the processes of policymaking with respect to the Norwegian National Action Plan for Construction and Demolition Waste (C&D waste). In 2001 the Norwegian AEC-industry voluntarily implemented the "Norwegian Action Plan for Construction and Demolition Waste" (NAP01). The goal of NAP01 was to reduce the amount of Construction and Demolition waste (C&D waste) to be deposited in landfills from 70 to 30% within the end of 2005. And although still 40% of the C&D waste ends up at the landfill by the end of 2005 (in opposition to more than 70% in 2001), the industry is optimistic, and seeks to introduce and implement a revised NAP early 2007 (NAP07), with new a new performance goal of less than 20%* deposition by the end of 2010. In this paper we outline how the stakeholders of NAP07 were introduced to, and made use of results from dynamic MFA and LCA based information in their work on revising the action plan. Of special interest is how the process of policy recommendations has shifted from an economic and mass handling motivated approach, to a more scientific founded approach in respect to prioritizing between waste fractions, and between the possible end-of-life solutions. Thus MFA and LCA has made a difference for the authorities and the Norwegian construction industry in designing new and more sustainable policies for the Norwegian AEC-industry with respect to waste management and recycling. * Since the work on NAP07 still is in progress, the number is not fixed yet.

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Dynamic Eco-Efficiency for Analyzing Sustainable Housing. (Theme B 19)

This paper investigates the effect of different development scenarios on the sustainability of Norwegian housings with respect to changes in energy supply, energy efficiency and dwelling stock (useful floor area /dwelling, capita/dwelling) towards 2050. Thus we have calculated how much eco-efficiency must improve in order to keep the environmental pressure from residential buildings at a near constant or decreasing level towards 2050 given the current trends of living. In earlier research we have shown that both the average floor area and energy usage in Norwegian residential buildings has increased significantly over the last 50 years, although dwellings has become more energy efficient on a pr. m^2 basis. But a significant shift away from solid and liquid fuel towards hydro-electric-power as energy source has kept the total environmental impact (as measured in eco-points by the eco-indicator 99 impact assessment method) from the Norwegian residential buildings at a near constant level. However, the hydro-electric production capacity can no longer sustain the increased domestic electricity demand, and new production capacity is about to be built. This paper analyses how different scenarios in energy consumption and sources of production, as well as trends in dwelling size does influence the future sustainability of Norwegian housings.

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Analysis of Waste Prevention Policies Applied at the Solid Waste Management in Brazil (Theme B 18)

This study aims to present the effects of Waste Prevention – WP on Integrated Solid Waste Management – ISWM, considering all stages of urban cleansing: Solid waste Production, Collection, Transport, Treatment, Recycling and Final Disposal. As the area of study, Porto Alegre – PA City has been chosen due to the fact of its Integrated Solid Waste Management System is known, internationally, as a good example in developing countries, with a recycling efficiency of 20% in 2005. In dealing with the solid waste, there are two fundamental requirements: reduce the amount of solid waste generated and then an effective system to managing the solid waste still produced. To achieve both fully, WP and ISWM are required. WP, a precursor to effective solid waste management, refers to any change in the design, manufacture, purchase, or use of materials or products to reduce their amount or toxicity before they become municipal solid waste. WP will affect the volume and the nature of the solid waste, but there will still be solid waste for disposal. The results demonstrated that environmental impacts and network costs decreased considerably, as a result of the application of waste prevention polices combined with recycling and composting processes. However, all these results depend on social acceptability of WP policies for local population. And it is only possible to implement an effective environmental education program if local government is compromised to set up the example. Environmental values are crucial when considering waste prevention, recycling and re-use intentions. Therefore, it is important to emphasize that environmental education is a long-term work, which needs to be focused in each target group, and it must be a commitment between present and future governments, with the objective to create a strong environmental consciousness among citizens, private sector and public sector.

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Toolkit Application for Regional Synergy Opportunities (Theme A 12)

In 2004 the Centre for Sustainable Resource Processing (CSRP) launched a number of research projects to promote further identification of regional synergies. These foundation projects featured two hands-on practical support projects for the Kwinana (WA) and Gladstone (QLD) industrial areas in Australia coupled with a higher level engineering and technology project for regional synergies. The primary aim of the latter project was to develop tools to systematically identify, evaluate and realise synergy opportunities in heavy industrial areas. To achieve this aim, a three-pronged project strategy was employed: (1) best practice review and promotion; (2) development and trial of a regional eco-efficiency assessment methodology; and (3) assessment of technology needs and opportunities. The prototype of the Regional Eco-Efficiency Assessment Methodology, which has now been developed, aims to enhance and facilitate the identification and development of synergy opportunities. In its final version it will represent a step-by-step routine with instructions on “how to” at each stage and comprise a number of enabling tools, such as datasheets, various templates, and importantly a toolkit to facilitate and aid businesses in their decision making process. The Technology Assessment Tool, which is currently under development, will evaluate and aid the selection of the appropriate technologies to enable regional synergies identified using the Regional Eco-Efficiency Assessment Methodology. The prototype of the developed methodology was trialled on Kwinana and Gladstone industrial areas, using data collected as part of the CSRP Kwinana and Gladstone practical support synergies projects. The results of the trial demonstrated that the methodology streamlines and enhances the identification and evaluation of synergy opportunities by providing the user with guidance and support for the tracking of the material, energy and water flows. The presentation illustrates how the toolkit produced a suite of potential synergy initiatives that closely matches those identified by the extensive and time-consuming work carried out as part of the above regional projects. In addition, the presentation shows the value of this methodology, which has been applied in other

industrial areas in Australia such as Geelong (VIC), in paving the way for promising opportunity assessments.

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Food or Energy? Towards Sustainable Land Use - A Life Cycle Approach for the Assessment of the Carbon Intensity of Land Use for Food and Bioenergy in the U.K. **(Theme A 9)**

This paper will report initial results from a study aimed at identifying more sustainable land use options for food and bioenergy crops in the UK. The emphasis is on carbon-equivalent emissions associated with different types of land use. The objectives are: • to develop a life cycle methodology to enable robust estimations of the inventories of carbon-equivalent emissions associated with the use of land; • to assess the current situation in terms of land use and to identify the hotspots with respect to carbon emissions; • and to assess the carbon emissions implications for economies trading food and/or energy with the UK, resulting from different biomass / food production possibilities in the UK. The scope of the study is from 'cradle-to-grave', encompassing the whole life cycle, from the extraction of raw materials through agricultural activities, production, use, transport and waste management. Two types of land use are considered: agricultural; and conifer and broad-leaved forest and woodlands. Together, these land uses comprise 88.3% of total land use in the UK (76.6% and 11.7%, respectively). The agricultural land uses to be included are grassland, cereal and other arable crops (wheat and oilseed rape) and rough grazing. These add up to 92% of UK agricultural land. The bioenergy crops to be considered are willow (Salix spp.) under a short-rotation coppice (SRC) regime, and switch grass (Miscanthus spp.). Their current proportion of agricultural land use is insignificant (0.01%) but would grow substantially if recommendations are to be followed and energy crops are taken seriously.

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Dynamic Life Cycle Energy Flow Analysis of Residential Building Systems – Contributions to Regional Metabolism in Norway from 1960 to 2040 **(Theme B 15)**

Built environment consumes a major part of society's energy flows, and it is important to understand the long term energy metabolism of the housing system. The Norwegian construction sector has undergone significant fluctuations due to economic cycles, but on the long term we find systematically and rapidly increasing energy flows, out of which a large part is related to residential buildings. This is due to the northern climate and the country's internationally exceptional strong socio-economic growth, particularly since 1950. Industrial ecology provides an excellent basis to examine this system and its influence with respect to regional and urban metabolism and sustainability. In earlier research we have carried out dynamic material flow analysis (DMFA) of the stocks and flows of useful floor area (m^2 and m^2/yr) and materials (tons and tons/yr) in the Norwegian system of residential buildings since 1800. This presentation takes this dynamics as a starting point, and examines the energy turnover that is associated with the floor area (kWh/m^2) and the processing of construction material inflows and construction and demolition waste outflows (kWh/ton). Hence, we provide a system-wide energy analysis in space and time, by help of a Matlab-Simulink model, examining the various types of energy source, flow values and end use purposes, empirically since 1960, and using scenario analysis towards 2040. The results demonstrate the model's ability to provide excellent quantitative insight and basis for environmental and economic system evaluations, useful for policy development with respect to the future energy efficiency and energy mix for the housing system. The use phase clearly dominate the system, and despite significant improvements in energy efficiency (kWh/m^2) the aggregated energy demand for the Norwegian housing system will increase until 2030.

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Barriers and Opportunities for Increased Use of LCA-Based Tools for the Built Environment - Stakeholders Responses **(Theme A 4)**

To achieve a sustainable society, great efforts are required from the government as well as from industry and municipalities. The construction industry has a key role to play in the creation of a sustainable society. The processes involved in the construction industry are though complex and for a project to be completed successfully, several different types of skills are needed (e.g. architects, suppliers and engineers). Environmental assessment tools have an important role to play in integrating sustainability into construction practice, as they provide a clear declaration of what are considered the key environmental consideration. This paper aims at clarifying barriers and opportunities for increased use of Life cycle assessment (LCA)-based tools for the built environment, especially the Environmental Load Profile (ELP). The research is a step towards further refinement of the ELP-tool that will aid in establishing it as an instrument of common acceptance. A questionnaire and complementary interviews with the construction sectors stakeholders were used as means to collect information. The main topics in the questionnaire and in the interviews were as follows: (i) the environmental work in Sweden's construction industry (attitudes, responsibility and driving forces) (ii) stakeholders responses on LCA-based environmental assessment tools (knowledge, understanding, needs and requirements) The results indicate that the preparedness to use LCA-based tools, such as the ELP is relatively low. The main barriers for increased use of the tools are connected to (i) time, (ii) costs, (iii) driving forces, (iv) knowledge and (v) requirements. Our study has also revealed the following improvements and opportunities for increased use of such tools: (i) different design of the tools for different users (e.g. focus on energy), (ii) connection to the forthcoming EU-Directive on the energy performance of buildings (iii) benchmarking for simplifying interpretation of the result

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Challenges and Perspectives of International Sustainable Resource Management (Theme A 13)

Recent case studies of platinum group metals (PGM) and biofuels/bioenergy are taken as examples that traditional environmental policy tends to solve certain problems at the expense of creating new problems in other regions. Based on a broader international comparison, driving forces of material resource use and related problem shifting will be presented. With regard to a future sustainable socio-industrial metabolism of economies like the EU, - drawing from ongoing research projects like FORESCENE and MATISSE - key sustainability elements will be described, and potentials for techological and institutional improvements will be addressed. The presentation will then discuss strategies for sustainable resource management which seem appropriate with regard to minimization of problem shifting across regions. Tasks for international resource management will be addressed and questions for future research will be described.

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Statistical Methods for Treating Uncertainties in Material Flow Analysis – Result Demonstrated with U.S. Zinc Cycle (Theme A 5)

In material flow analysis, flows and stocks data are acquired from very different sources, thus have very different accuracy. In some cases, they are not measured at all. Uncertainties not made explicit induce a misleading accuracy, which can lead to inaccurate or wrong conclusions and false policy recommendations. There are a few existing methods to treat uncertainties in MFA study. Tom Graedel is the first to make the closure balance explicit in the flow diagram; Hedbrant and Soerme have introduced method to calculate uncertainty of dependant variable based on raw data with normal distribution; Bader and Baccini have introduced a statistical method to adjust flow data with normal distribution so that the mass balance can be satisfied. In reality, however, data with larger uncertainties may be better modeled with lognormal distribution . In this paper, we will propose a new approach to adjust flow data with lognormal distribution so that the closure balance can be eliminated, and to reduce uncertainties with statistical methods. We will demonstrate the result with the United States zinc cycle of year 2000, and compare it with the existing methods to treat uncertainties in MFA.

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Determinants for an Industrial Ecology Model in Mexico. Altamira's Industrial Park (Theme C 22)

Industrial ecology is the result of an eclectic view which connects the fundamental principles of economy with those of biology as a natural ecosystem that describes a particular distribution of fluxes of materials, energy and information. The paradigm in this approach is the experience carried out in the municipality of Kalundborg, Denmark. However, when efforts have been made to reproduce this experience in different contexts, other determining factors – which go beyond the technical compatibility or the geographical proximity- appeared to be crucial for the success of this strategy: the trust relationships between executives, the presence of the leader,the inter-managerial communication and cooperation, the learning processes throughout the time, the norms that regulate the interactions between agents and the industrial and environmental policies of the country . In this research the different determining factors for the success and limitation of the project developed on industrial ecology -carried out in 1997 in the northern Mexican Altamira Industrial Complex - are analysed. Until now this project has followed a dynamic of permanent innovation orientated almost entirely towards the development of eco-efficiencies instead of synergies. The role that the regional Industrial Association and the corporative environmental policy had in this process is highlighted here. It is also pointed out how certain environmental policies in the country only inhibit the expansion of this strategy. Finally, it is necessary to incorporate some elements of inter-managerial cooperation and evolutionist economy into the theoretical apparatus of the industrial ecology model .Those elements point out the importance of the learning processes developed throughout time and facilitate the consolidation of collective actions.

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Measuring Eco-Industrial Development: Evaluation of Resource Consumption and Performance Indicators in a 'Typical' Canadian Industrial Park (Theme E 29)

Sound decision-making depends on our ability to measure our performance, allowing us to learn and adapt from our successes (and failures). Performance indicators help us to measure our performance in a systematic, consistent, and rigorous way. The lack of measured (or measurable) results has been a barrier to successful implementation of eco-industrial networking (EIN) (and the development of eco-industrial parks) across Canada. Standardized, rigorous measures facilitate the tracking of costs and benefits of innovative solutions like EIN. While anecdotal evidence and descriptions of the benefits are motivational, quantitative, demonstrable benefits are an effective means to engage the business community and secure financing to implement EIN. A review of eco-efficiency and sustainable community indicators found that none were able to provide a complete picture of sustainability performance of industrial areas. The framework outlined in this session brings together and adapts the reviewed indicators, so that they can be applied to measure the sustainability of industrial or business parks. This session focuses on those indicators that could be normalized to provide for meaningful comparison from site to site, and for which data was likely available. After presenting the indicator framework, we will discuss testing this framework in an industrial park in Regina, Saskatchewan. The Ross Eco-Industrial Park project is an initiative being run by the Regina Eco-Industrial Network Association, in partnership with several local businesses, the City of Regina, and federal funding agencies. The primary objective of the project is to identify EIN opportunities for sustainable transportation in the area; but the project is also the first in North America to form a detailed resource baseline for an industrial park, using the sustainable industries performance indicator framework. We will discuss the challenges and strengths of the framework in the Ross context.

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Map it! Harnessing Geographic Information Systems for Applied Industrial Ecology (Theme E 29)

Eco-industrial networking (EIN) is a tool for implementing the principles of industrial ecology. EIN supports collaborative partnerships, or networks, between businesses, local governments, and wider communities resulting in more sustainable resource use. EIN opportunities incorporate strategic, niche-based economic development; by-product synergies; ecological design; green and integrated infrastructure; and shared business services. Geographic Information Systems (GIS) is a rapidly growing technological field that incorporates graphical features with tabular data in order to assess real-world problems. New uses for GIS are always being developed and its usage is becoming increasingly widespread. Today, Industrial Ecology is becoming the latest field to take advantage of GIS. In order to effectively identify and evaluate EIN opportunities, accurate and recent data is mandatory. This includes data for individual businesses, municipal land uses (including building footprints), and local utilities (e.g. natural gas, electricity, and water consumption) all of which is even more effective and useful if it can be presented spatially. This presentation describes EIN cases employing GIS to manage and present data, and to identify context-appropriate EIN opportunities. For example, Greater Sudbury's Regional EIN Strategy employs GIS to manage data for >9,000 businesses and local utilities. Ultimately it will support an online synergy-finder tool for local businesses to identify and participate in EIN opportunities. For Ross Eco-Industrial Park (Regina, Saskatchewan), GIS is used for ground-truthing the Sustainable Industries Performance Indicator Framework. For some indicators, GIS can be used to identify "hot spots" of energy and water consumption, making it easier to evaluate the feasibility of EIN opportunities. This presentation also highlights key challenges and opportunities related to the adoption of GIS, particularly the availability (or lack thereof) of necessary data, as well as the need to 'clean it up' prior to input into GIS.

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Current Activities toward to Eco-Industrial Estate of Map Ta Phut Industrial Estate, Thailand
(Theme C 22)

Map Ta Phut Industrial Estate (MTPIE) locates in Rayong province, eastern of Thailand. It was developed by the state enterprise, Industrial Estate Authority of Thailand (IEAT), Ministry of Industry, to serve industries that use natural gas as the main raw material development. Regarding to the expansion of industry in MTPIE area, the development of eco-industrial estate and networks project in MTPIE began in 2000 in order to develop the industries in harmony with environment and society. A recent study of the eco-efficiency in MTPIE area has been initiated by the Thailand Research Fund (TRF) with the corporation of Mahidol University and IEAT. The industries in MPTIE area were divided in 5 groups, which are Petroleum and Petrochemistry group, Chemical group, Iron and Steel group, Industrial Gas group, and Facilities group. The material balance and flow analysis were used as a method to study the relationship of each industrial group in MPTIE. The Eco-Forum meeting has been started to develop the corporation among industries in MPTIE area. The eco-efficiency of each industrial group in MPTIE was measured. The results from the eco-efficiency project can be served as an industrial policy and strategy for business development in MPTIE area in the future.

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Hybrid LCA Model Specific to Oil Sands Technologies **(Theme A 4)**

A current and developing activity within life cycle assessment (LCA) is the building of hybrid life cycle models, which offer a large spectrum of potential applications for industrial processes. Hybrid LCA combines the specific details of process-based LCA with the economy-wide scope of Economic Input-Output Life Cycle Assessment (EIO-LCA) and thus solves the problem of limited boundary definitions. An efficient tool to assess the resource use and the environmental impacts of current and new industrial technologies, hybrid LCA can be powerful in guiding effective decision-making. We construct a hybrid model for assessing the environmental impacts of oil sands technology using the new Canadian EIO-LCA model developed at the University of Toronto and process data gathered from industrial collaborators. The EIO-LCA model includes intersectoral resource flows over the whole Canadian economy, while the conventional process-based LCA incorporates technology-specific material and energy balances, not captured in national accounts, in order to make a complete life cycle model. Through the hybrid construction, energy sectors of the EIO-LCA model are disaggregated, and technological factors specific to oil sands processing and regional economic aspects pertaining to the province of Alberta are combined into the model. Note: This abstract focuses on the construction of the hybrid model. The application of the model to a comparison of the relative effects of oil sands technologies has been submitted as a separate abstract by Joule Bergerson and David Keith from the University of Calgary.

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Research on Method of Making a Master Plan of EIP for the ETDZs in China – A Case Study of the Fuzhou ETDZ (Theme C 22)

Today in China, the economic and technological development zones (ETDZs) play a very important role in the industrial development, therefore the constructions of eco-industrial parks (EIPs). Among the 19 national pilot eco-industrial parks (EIPs) that have been “approved to establish” by the State Environment Protection Agency (SEPA) till the September of 2006, 9 are based on the ETDZs. In order to make a master plan of EIP and implement it for the ETDZs, it is very necessary to understand the real meaning of EIP, also the special development mode of the ETDZs and its influences to the construction of EIP. Basing on the Fuzhou ETDZ, this paper discusses about the aforementioned and brings forward a method of making a master plan of EIP for ETDZs. Aiming at promoting the industrial symbiosis (IE), the plan should pay attention to four aspects: (1) The development plan of certain industrial sectors. It is necessary to develop one or several main industrial sectors for the construction of EIP. In the Fuzhou ETDZ, an eco-industrial cluster, the electronic and communication industrial cluster, and two eco-industrial chains are included. (2) The ground layout. The nearness of certain enterprises will promote the development of IE, so the ground layout should pay attention to the layout of all enterprises. (3) The systemic construction of infrastructures for the water, energy and solid waste. (4) The financial and tax policies that will promote the enterprises to take part in the constructions of the IE.

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Industrial Ecology and the Circular Economy in China (Theme C 20)

Given the enormous challenge for China of sustaining rapid economic growth while reversing environmental degradation, the country has been seeking a new industrialization model as the critical pathway for reconciling these goals. A key strategy advanced for this new development path is that of the "Circular Economy" which is disseminating in policy arenas and is likely to become law in 2008. As envisioned thus far, the circular economy concept calls for very high efficiency in resource flows as a way of sustaining improvement in quality of life within natural and economic constraints. This paper demonstrates the critical link between industrial ecology and the emerging ideas of the circular economy and shows how industrial ecology concepts can provide the intellectual foundation for this important change in course for China. Presently, ll regions and government departments have been instructed to use the circular economy as an important guideline in designing development plans at three levels: in the production state, in the waste generation stage, and in the consumption stage. Four areas have been chosen below to illustrate how an industrial ecology foundation provides a logical underpinning for the circular economy. With regard to production, the challenge of extending environmental management especially to smaller, outlying companies could use the lifecycle policy of greening the supply chain. Having already designated sixteen eco-industrial park demonstration projects through the Chinese State Environmental Protection Administration, knowledge of industrial symbiosis increases the ability to reduce flows at the inter-firm level. Recent attention to sustainable consumption in industrial ecology needs to be tailored to a developing country setting, but is also shown to be useful in shaping a circular economy. Finally, a close look at the waste management system shows that integration of low technology and higher technology solutions are possible without radical adjustment to waste collection infrastructure.

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Toward a Theory of Industrial Symbiosis (Theme E 29)

The study of industrial symbiosis over the last fifteen years has repeatedly shown that some industrial ecosystems thrive while others never do. To explain this, scholars have examined numerous literatures from ecosystem ecology to economic geography to sociology. What part of each of these is useful to developing a theory of industrial symbiosis? What ideas can first explain and eventually be used to make predictions about the emergence and development of these systems? To build a theory of industrial symbiosis we explore some economic theories including transaction costs and agglomeration economies to explain the observation that through the addition of industrial symbiosis, negative externalities can be reduced while increasing production efficiency in multiple industry industrial parks (Chertow, Ashton, Espinosa 2006). From ecology and complex system theory comes the idea that rather than function as closed-loop systems to optimize by-product reuse, the key element underlying industrial ecosystems could be self-organization that is characteristic of resilient systems. Social theory may be most powerful in recognizing the emergence of a symbiosis as representing a change in the culture of normal business activities from independent actions to interlinked and coordinated ones (Ehrenfeld 1998). Additional interaction among firms can result in the transmission and embedding of this new element in a way that deepens the new (symbiotic) behavior. Blending these themes and describing the mechanisms that enable them not only can advance theory, but also lead to a clearer understanding what makes industrial ecology themes novel in the marketplace of ideas.

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Re-Inventing Metalworking Fluids: A Case Study in Greening the U.S. Manufacturing Sector
(Theme F 34)

A metalworking fluid (MWF) technology that is novel, environmentally preferable, and capable of rapid diffusion into the industrial sector has been developed. The process of creating this technology represents a holistic approach to technical innovation that proceeds from conception, technology-proof-of concept, performance evaluation, life cycle assessment, through to technology transfer. Metalworking fluids were selected due to the well-documented environmental and occupational health impacts they present. Despite this threat they are ubiquitous: over 2 billion gallons of MWFs are used annually in the North American manufacturing sector to lubricate and cool in machining operations. The new technology was developed to perform these functions using supercritical carbon dioxide ($scCO_2$) and vegetable oils eliminating the need for large volumes of petroleum products and water. In the new process, an oil-in-CO_2 dispersion is sprayed out of a nozzle at high speed and pressure to deliver oil and form dry ice near to the cutting zone in minimal and precise quantities. The rapid expansion of the CO_2 leads to cooling at cryogenic temperatures, and the combination of high pressure and low surface tension provides access to interstitial spaces that are inaccessible to conventional MWF oil and water jets which, in many cases, leads to increased performance over conventional fluids. A life cycle study of the new technology suggests that its corresponding environmental impacts are significantly lower than those of conventional MWFs. In particular, greenhouse gas emissions of the new system are lower depending on allocation strategies due to the industrial use of feedstock CO_2 that is a byproduct of other processes. Preliminary work with several U.S. auto and aerospace manufacturers suggests that the technology has the potential to quickly diffuse into the market.

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Building and City-Scale Cost Gap Analysis for Green Roof Implementation (Theme B 15)

Green (vegetated) roofs address the multifaceted, complex environmental problems of urban centers. Policies that encourage green roofs exist at the local and regional level (e.g. Berlin, Germany; Tokyo, Japan; Chicago, USA); however, for markets within the USA and Canada, installation costs remain at a premium deterring investment in this technology. In addition to increased green space, major policy drivers are the green roof's ability to reduce stormwater runoff and building energy consumption. Increasing evidence suggests that green roofs may play a significant role in urban air quality. This research quantitatively integrated the stormwater, energy, and air pollution benefits of green roofs into an economic model capturing both the building-specific and city scale. A net present value (NPV) analysis comparing a conventional roof system to a green roof system found that at the end of the green roof's lifetime the NPV for the green roof under the current valuation scenario was 28% less than the NPV for the conventional roof. Preliminary results indicated that the inclusion of air quality benefits through the uptake of NOx pollution translates to $0.97 and $1.01 per square meter of vegetated roof based upon public health cost estimates by the US EPA and other programs of $5280 to $7350 per metric ton of NOx pollution. The additional air pollution benefit further reduces the green roof NPV by 7% resulting in a total NPV that is 35% less than the conventional roof. Considering the public health benefits at the urban scale, greening ten percent of metropolitan Chicago rooftops would result in 3.3E4 to 3.7E4 Mg of NOx reduction (from uptake and reduced energy production) resulting in savings of 170 million to 190 million US dollars annually. Including air pollution mitigation into innovative policies can reduce the cost gap that currently hinders investment in green roof technology.

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Management of Food Supply Chains: the Relationship between Supply Chain Governance and Eco-Efficiency (Theme E 30)

The distribution of ecological impacts and of economic and social benefits along the supply chain has sometimes been advocated as an indication of supply chain sustainability. In this work, the approach has been developed and applied to fresh fruit and vegetable produce supplied by a major UK retailer. The analysis combines LCA, used to identify the principal environmental impacts and the supply chain stages where they arise, with Value Chain Analysis (VCA), used as a “soft system” analogue of LCA to characterize supply chains in terms of the level of influence exercised by each agent in the supply chain; i.e. the governance pattern of the supply chain. The VCA approach is complementary to current attempts to extend LCA to address social as well as environmental impacts. The combination of environmental LCA and socio-economic VCA reveals the nature of supply chain governance and how it differs between specific supply chains. This approach has been applied to developing guidelines to help the retailer’s buyers make decisions over sourcing options which recognize the effects of these decisions on their suppliers and other stakeholders.

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Identifying Secondary Materials Markets in Portugal: the Role of Waste Stock X-Changes
(Theme A 13)

In the new Waste Framework Directive proposal, of 2005, the European Commission introduces the legal figure of secondary material, which includes a shift from waste to a potential use of materials and substances, by considering the development of a secondary materials market. However, there are no tools available to assess the functioning or the regulation of such markets or, the scope of its application is limited to a small number of waste streams, namely compost and recycled aggregates. This paper focuses on assessing Waste Materials Exchange (WME) programs as a tool for analyzing and stimulating the development of a systemic secondary materials market, thus assisting the implementation and development of the new EU waste policy. WME programs can provide the means to analyze material flows, secure commitment to environmental and technical standards of the traded materials and assist the exchange between companies, by acting together with government institutions. This analysis is conducted through a benchmarking analysis of several WME programs already implemented, focusing on key-factors, both legislative and technical, that allow its success. These criteria are applied in an EU context scenario – the Portuguese case – and the results obtained are analysed to and conclusions are drawn on the potential outcomes of adopting WME programs, especially in the waste management outline of the country. It is concluded that, to capitalize on the full benefits of the new EU waste proposal, a clear definition of secondary material is critical, in particular, based on the establishment of specific criteria, as well as the promotion of tools that allow a diffusion of its use. WME programs can assist in implementing EU waste policy, and provide the means to stimulate secondary material use, as well as monitor its development, as long as there is a strong governmental support.

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Development of a Metamodel for Informing More Sustainable Urban Development: Preliminary Results (Theme B 15)

A metamodel concerning the interactions among social decision-making, land development, energy and material use, and their environmental impacts was constructed to inform more sustainable urban planning. The metamodel framework comprises four interactive components: urban growth simulation, material demand quantification, life-cycle analysis, and air quality simulation. Urban growth was simulated by a land-use model UrbanSim, which projected urban development patterns that allow one to quantify construction material demands and ozone precursor emissions, and provide information of land-use type for ground-level ozone simulation. Demands for construction materials were quantified for two residential construction scenarios, i.e. one-story vs. two-story residential buildings. The results show that the two-story residence scenario would use 32% less raw construction materials by mass than the one-story residence scenario would. Life-cycle analysis was performed using ATHENA™ Environmental Impact Estimator version 3.0.1 to compare the environmental impacts of one-story and two-story residential buildings. Without considering the operational energy, the embodied energy of the two-story house (889 GJ) is 6% less than that of the one-story house (946 GJ), and the two-story house generates 10.2% less solid waste, 5.5% less air pollution, and 6.1% less green house gas emissions. The operating energy consumptions for the two designs are similar Ground-level ozone concentration, one of major air quality concerns in Phoenix area, was projected by two steps. First, the ozone precursor emissions from mobile, point, area, and biogenic sources, as well as from the construction of residential buildings were estimated. Second, spatial and temporal distribution of ground-level ozone concentration was simulated using the Penn

State University/National Center for Atmospheric Research Mesoscale Model 5 (MM5) and the Community Multiscale Air Quality model (Models-3/CMAQ). The simulation shows that due to the decrease in the ozone precursor emissions the ozone concentrations are slightly lower in the 2015 future year than in the 1999 base year.

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Fundamental Analysis of Carbon Emissions for Manufacturing with Aluminium and Steel (Theme F 34)

The industrial sector consumes 27 percent of the world's final energy and is dominated by the production of primary materials: concrete, steel, aluminium, paper and petrochemicals. Any strategy targeting a 'low carbon economy' must consider carefully the energy consumed in the processing of primary materials. An engineering approach is taken to reducing carbon emissions by exploring energy efficiency technologies specific to aluminium and steel industries. This paper presents a case study of aluminium and steel beverage cans and explores the fundamental limits to energy efficiency. Strategies for energy reduction are divided between process efficiency improvements within the manufacturing process and potential non-process energy reductions. <Process efficiency improvements> Energy use resulting from primary materials processing and beverage can manufacture is examined at each process stage. Current energy use is estimated from international energy sources, sector reports and industry data. This is compared with the calculated minimum theoretical energy requirements for each process. The resulting difference or ‘energy gap’ represents the available energy reduction opportunity. Potential technologies for closing this ‘energy gap’ are then evaluated in detail. <Non-process energy reductions> Three additional non-process strategies are examined: material reuse, dematerialisation and material substitution. Primary production of virgin metals is an energy intensive process. Therefore the potential energy reduction from the reuse and recycling of materials is estimated. The sensitivity of the energy analysis to mass reduction of the beverage can is examined. Comparisons are also made between aluminium and steel cans, and other alternative beverage container materials. Defining fundamental minimum energy limits for aluminium and steel manufacturing helps to highlight potential technology routes for reducing energy consumption. This is essential for prioritising engineering responses to industrial carbon emissions.

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Island Limits: The Physical Dimension of Sustainability in Ireland **(Theme A 1)**

Since the early 1990's Ireland has undergone a period of unprecedented economic development, however this has been coupled with increasing resource use, environmental degradation and social inequality. There was a clear need for research on material flows and resource use to place policy and decision making on an evidence based footing. Island Limits was the first full economy-wide material flow analysis and ecological footprint of Ireland. The material flow elements of the programme comprised of two complementary analyses, an economy-wide material flow analysis and an environmentally extended input-output analysis of the Irish economy for 2003. The calculation of the economy-wide MFA and derived indicators (DMI, DMC, DMO, DPO, resource efficiency and intensity) demonstrated that Ireland has high material input and consumption compared to other European countries and would need to increase its resource productivity by 25% to reach the European average. The analysis also identified those industrial sectors which are 'big hitters' in terms of direct material consumption, namely 'mining and quarrying' and 'agriculture'. Domestic industrial production was analysed using environmentally extended I-O analysis and the direct and indirect material requirements needed by sectors to meet their final demand categories quantified. The construction sector had the highest total material requirements using 36% of material inputs followed by food and beverages (24%). Only 17% of material inputs required by domestic industry were to meet final demand for households, with 43% demand for exports. Separate analyses were also carried out for biomass, metals, fossil fuels, minerals and imports. The completion of the economy-wide MFA and the environmentally extended I-O analysis in parallel has enabled a comparison of the strengths, weaknesses and complementarities of each approach.

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The Relationship between Changes in Carbon Economic Intensity and State Economic Performance: How Do Changes in Carbon Intensity Affect Economic Growth? **(Theme A 11)**

In the media and in the economics literature (at least in the United States) we quite frequently hear that any reduction in carbon intensity is likely to greatly hurt the US economy. Economic growth will decline and unemployment will increase. We have set out to econometrically assess this claim by performing a rigorous statistical analysis of the relationship between carbon emissions economic intensity (CEEI) and state economic performance in the United States. In particular we are interested in knowing if: 1. Reductions in state level CEEI are associated with weaker state economic performance as measured by per capita GSP. 2. Whether a causality relationship can be established between CEEI and economic performance. Data for the analysis is arranged in to panels, covers 48 states, and extends over two decades, from 1980 to 2000. The results reveal a number of important findings concerning the relationship between carbon emissions intensity and state economic performance and, implicitly, the policies and programs that states may implement to jointly achieve reduced carbon emissions intensity and improved economic performance. Key findings include: a favorable (i.e., declining CEEI accompanied by increasing per capita GSP), bi-directional causal relationship between changes in CEEI and changes in per capita GSP. At the sectoral level, the results indicate for the commercial, industrial, and transportation sectors, favorable and causal relationships between these sectors' CEEI and their contribution to per capita GSP, implying that CEEI declines in any of these sectors are expected to be accompanied by an increase in the per capita GSP contribution from these sectors. What the results imply is that state governments should be able to target programs towards the commercial, industrial, or transportation sectors to achieve simultaneously (1) improvement in sector-specific economic performance and (2) reduced carbon emissions economic intensity in these sectors.

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Industrial Inertia and Industrial Change: Opportunities and Constraints for Environmental Policy **(Theme D 26)**

Understanding the factors that influence the dynamics of industrial systems – their use of inputs and quantity and composition of outputs – is a fundamental prerequisite to properly anticipating impacts of energy and environmental policies on industrial change and its corollary industrial energy use and greenhouse gas emissions. For example, most mature capital-intensive industries such as the metals industries, the chemical industry or pulp and paper use capital stocks with large capacities and long service life. Typically investment is lumpy and occurs at irregular intervals, thus causing differences between the efficiency of new and existing capital to become increasingly pronounced over time. Changing input mix and efficiencies of installed capital is often difficult in these industries, which limits the leverage that policy may have on industrial change and their environmental performance. This presentation presents an analysis of the extent of capital inertia in three industrial systems, and the impact of the observed inertia on the ability of those industries to react to changes in the external policy environment. The results demonstrate notable regional and industrial differences in the extent of capital inertia and the impact of inertia on industrial change. The results further indicate, as a direct result of the observed inertia, the potential direct and indirect benefits or costs of using a price driven versus an investment-led strategy to influence the evolution of industrial systems and thus energy, material and carbon intensities.

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Agroparks - Food Production in Deltametropoles
(Theme A 9)

Feeding the increasing population in Deltametropoles without degrading the environment is one of the major challenges in the coming decades. Intensive, large scale farming is efficient, but is often detrimental to the environment and the landscape. In Agroparks, farms and food processors from different sectors (for example horticulture, pig farming, fisheries) are clustered in order to create opportunities for industrial ecology. This clustering has major advantages over the present monocultures of farms which are not interconnected. Resources such as water, minerals, energy and CO_2 (for plant growth) are used more efficiently, due to the closing of material cycles. Furthermore, transport will be substantially reduced, since the production chain is predominantly local and the consumers are nearby. Finally, by reducing the contacts between people and animals, the risks of tramsfer of diseases and outbreaks of pandemia will be drastically reduced.The Agropark concept means a radical change in agriculture production and land use. For example, industrial estates and harbours will become the natural habitat of the future farms and the related processing units. This allows the countryside close to megacities to be used for other purposes, such as recreation and nature preservation. In The Netherlands the possibilities of this concept have been elaborated and Agroparks are presently developed on several locations. The concept is also relevant for developing countries, such as China, with the rural population moving to the cities and the traditional farming being unable to cope with the growing food demand. For the Shanghai area the Agropark concept has been tailored to local conditions. The ratio of this concept and its implications will be presented on the basis of various cases in The Netherlands and other countries.

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Horticulture City **(Theme B 15)**

InnovationNetwork has developed concepts for connecting horticulture with the urban environment. The technology has been developed to harvest heat in greenhouses during the summer and store the heat below the groudn in aquifers. Interestingly, not one technology, but several competing systems are now available on the market. The most integral system also provides solutions for water saving, energy generation and recycling of nitrogen. The remaining complex questions are the organisational structures and different roles that have to be played by both government officials and commercial companies. The horticultural sector is now competing with the traditional energy companies to deliver heat to thousands of houses. The sustainable impact of the system is enormous: heat and cold can be generated completely sustainable, drinking water can be reused for 95%, and 50% of the needed electricity can be produced within the system. With additional biomass, the electricity production can also be made completely sustainable.

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Historical Perspective on Environmental Kuznets Curve and Porter Hypothesis. **(Theme E 28)**

Much efforts have been devoted to study the validity of the Environmental Kuznets Curve (EKC) and the Porter Hypothesis (PH). Present-day scholars, however, have yet to realize that the processes now described under these names have been widely discussed since at least the middle of the 19th Century. This paper reviews this earlier literature and discusses its main arguments and insights, which are then illustrated by past case studies of industrial waste management.

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Helping RDAs to Shape a Biobased Cluster - the Costa Due Case (Theme C 26)

The objective of the Costa Due project is to let a biobased cluster emerge in the Eemshaven and Delfzijl harbor locations - the Eemsdelta, which is situated in the North of the Netherlands. The initiative was developed by Groningen Seaports, the regional development agency (RDA) and Groningen Province. Partnering with other stakeholders in the region, the Costa Due partners have organized a successful social process to increase awareness of the initiative. Thereby the interest of authorities, companies, consultants, universities etc. was raised and an effective regional social network was created. An important objective of this social process was to stipulate entrepreneurs, SME's as well as energy companies and process industries to develop suitable investment projects. To date, some 50 ideas have been generated by a total of some 80 stakeholders. The RDAs, however, had largely focused on the social network and individual biomass transformation processes. How to move forward and convert these ideas into real projects - hardware installed and operative on-site? This question has been addressed by completing a systemic study to underpin the RDAs strategy development (Dijkema and Stikkelman 2006). Therein 1. relevant trends - global, continental, national, regional - were inventoried and analyzed for impact on biobased cluster development 2. the biomass system was analyzed as a set of interconnected supply-chains that run from soil to customer 3. the competitive position of the Eemshaven en Delfzijl harbor locations vis-à-vis harbor location in North-West Europe was evaluated 4. the criteria used by companies for investment and location decision were determined The integrated framework for underpinning and assessing the feasibility of Greenfield biobased cluster development will be presented, conclusions drawn and recommendations given. Finally, the program for transition will be elaborated wherein targeting specific biobased cluster content was combined with a recipe for action for the RDA's.

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Complexity, the Holy Grail for Industrial Ecology? **(Theme D 26)**

Industrial ecology (IE) is defined as a multidisciplinary, "system-oriented concept [which] suggests that industrial design and manufacturing processes are not performed in isolation from their surroundings" (Graedel, 1993). In IE, the emphasis seems to be on systems analysis rather than "bringing systems into being" and the decision-making involved. Both in nature and our industrial society we can discern complex, layered and dynamic systems that interact with their environment and thereby each affects the other. Over time, systems evolve and complex structures emerge as a result of multiple interactions and feedback loops. A distinct characteristic of our industrial system is that it evolves as a result of decisions made by sentient beings related in a social network. Therefore we believe that the study of the nature of and the inter-relations between socio-technical and biophysical systems is core to IE. We conjecture that Complex Systems Theory (CST) can contribute to the future of IE by underpinning “bringing-systems into being” through guided evolution. We will explore whether Complexity is the Holy Grail of IE, and what (not) it has to offer. At the theoretical level, CST challenges some of the fundamental conceptions and attendant endeavours of the IE community. At the practical level, under the banner of CST, a range of methodologies and associated tools may enhance the quality of analysis and recommendations for sustainability. The notion of evolution instead of design, of emergence instead of prescription, causality instead of intentionality have much to offer and may help bridge the gap between system understanding and shaping, between the content and process in transition management, between technology and decision-making. Thus, it appears that without a serious engagement in CST well-intentioned efforts, work in IE may ultimately perpetuate unsustainable practice rather than enable and promote the adoption of sustainable human activities.

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Sustainability Limits of Products Designed for Multi-lifecycle (Theme A 8)

Design for multi-lifecycle (DFML) is a sustainable design approach that maximizes the utility of resources used in developing a technology by incorporating at the design stage, features that enable the elongation of the techno-economic service life of that technology. The goal of DFML is “indefinite” use of the resources invested/embodied in a technology without compromising its economic reasonableness, technological soundness and social-cultural acceptability. However, there is a limit to reusability soundness of these resources in the subsequent lifecycle of technologies designed for multi-lifecycle. This paper articulates the various factors that determine the sustainability limits of technologies designed for multi-lifecycle, their correlations and how they can be used to estimate the remaining sustainable life of such technologies.

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Global Socio-Metabolic Patterns of Copper and Aluminum– Past Trends and Future Options
(Theme A 1)

Metal ores are resources which are widely used and of strategic importance for industrial economies. The production of these raw materials has been forcefully globalized in the past decades. In the European Union, e.g. domestic production dramatically declined and ores are increasingly imported. The domestic resource dependency (DE/DMC) for all metal ores together, was 60 % in 1970 and 20 % in 2001. The industrial economies are depending on a constant supply of these resources at high levels and the rapidly industrializing economies such as China and India need exponentially growing quantities. This has two important consequences. For the empirically oriented analyst the globalized production system of metals makes it difficult to link the consumption pattern of a country or world region, such as the EU, to the amount of raw materials that were needed in the upstream production chain. From a conceptual point of view the global trends of socio-economic metals use bear all signs of a transition towards an industrial metabolism which is, in all cases studied so far, connected to a multiplication of the per capita material throughput. At the examples of copper and aluminum we investigate patterns of global production, consumption, waste generation and trade flows. Using GIS representations we will provide spatially explicit data on the past development and present state of the global social metabolism of copper and aluminum. We will discuss these results in terms of sustainability challenges, such as environmental pressures associated with production and consumption, relevance for the industrial metabolism, geopolitical concerns, or issues of scarcity and inequality and finally options for the future.

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Costing Tool for Sustainable Neighbourhood Design **(Theme B 19)**

There is mounting evidence that more compact, mixed-use development is a more cost-efficient and environmentally sustainable form of development than low-density suburban development. This is particularly the case when one adopts a holistic approach to the assessment of neighbourhood costs that considers the capital and operating costs of hard infrastructure and municipal services, personal travel and space conditioning costs, and external environmental and health costs, among others. However, there are very few readily available tools to demonstrate the degree to which this is true, or to effectively compare different types of development. To address this need, IBI Group (under the direction of the Canadian Housing and Mortgage Corporation – Canada's national housing agency), has led development of the 'Sustainable Neighbourhood Costing Tool'. Using this tool, developers, municipal decision makers, and citizens can produce a picture of the magnitude and distribution of neighbourhood capital, operating, and maintenance costs, and compare how these costs change across different neighbourhood scenarios. Estimated outputs include the key capital, operating, and lifecycle costs and revenues associated with hard infrastructure (e.g., roads, sewers, schools, recreational facilities, etc.), municipal services (e.g., police services, public transit, etc.), personal needs (e.g., automobile ownership, home heating, etc.), and external costs (e.g., greenhouse gas emissions, motor accidents, etc.). Green infrastructure alternatives, such as bicycle and pedestrian paths, green roofs, and xeriscaping can also be considered. This tool has been applied to conventional suburban and neo-traditional designs for an existing Ottawa neighbourhood to assess and compare the lifecycle costs of different neighbourhood designs.

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Sustainable Water Metabolism: The Toronto Port Lands Design Challenge (Theme B 16)

The Toronto Port Lands were the focus of a design challenge that endeavoured to revitalize the underutilized industrial area into a sustainable, mixed residential community. The water management strategy for the proposed design took a holistic approach incorporating the sustainable metabolism of potable water, stormwater, wastewater and sludge to meet both human and ecological requirements. To minimize the consumption of potable water and the discharge of waste, the scheme exploited the harvesting of stormwater, the reuse of greywater and the beneficial use of sludge. A 59 percent reduction in water consumption can be achieved merely with the installation of water-conserving appliances and fixtures. Reusing greywater for toilet flushing can reduce consumption by an additional 7 percent. Combining excess greywater with harvested rainwater meets residential outdoor water demands. Wastewater sludge is composted onsite and used as fertiliser in urban gardens, thus closing the nutrient cycle. In addition to rainwater harvesting, a significant volume of stormwater is infiltrated in open spaces, permeable surfaces and vegetated swales. Using analytical probabilistic modeling, the expected runoff volume for the proposed design was estimated to be 48.7 mm/year, which is a 78.7 percent reduction in runoff for existing site conditions. By incorporating a 35 percent tree canopy cover, runoff can be reduced by an additional 6.8 mm/yr. Stormwater volumes that exceed the capacity of the site are diverted to a constructed meandering channel and retention pond for treatment. The proposed water system presents an example of the level of sustainability that is achievable when technological limitations are overlooked and barriers to innovation and creativity are removed. It also demonstrates how synergies with other urban systems and the natural environment can be accommodated. Finally, the proposed design meets international guidelines such as the LEED rating system and the Blue Flag Campaign for public beaches.

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Analyzing Impacts of the Global Socio-Economic Biomass Metabolism on Terrestrial Ecosystems
(Theme A 9)

Human appropriation of net primary production (HANPP), the aggregate impact of land use on biomass available each year in ecosystems, is a prominent measure of the human domination of the biosphere. It measures changes in the availability of trophic energy in ecosystems resulting from land use and can be unambiguously attributed to specific societal activities, which makes it particularly valuable for linking socio-economic and ecological dimensions of global/regional environmental change. HANPP results from (1) changes in productivity caused by land-cover change or land use, and (2) biomass harvest. This paper presents the first comprehensive spatially explicit assessment of global HANPP for the year 2000, based on vegetation modeling, agricultural and forestry statistics (FAOStat), and GIS data on land use, land cover and soil degradation, localizing human impacts on ecosystems. Aggregate global HANPP was found to amount to 14.7 Pg C/yr or 22.4% of potential NPP in the year 2000. This is a remarkable impact on the biosphere caused by just one species. Agricultural practices, i.e. cropping and grazing, contribute 74% to overall HANPP (cropping 52%, grazing 22%), forestry, infrastructure and human-induced fires share the remaining 26% about equally. The results imply that currently envisaged large-scale schemes to substitute biomass for fossil fuels should be viewed cautiously. Furthermore, we will present trends of major HANPP components in the 20th century, discuss global patterns and dynamics of biomass harvest and land use and identify important socio-economic and natural factors determining the pattern and dynamics of HANPP, paying special attention to the relations between land use, population density, economic development and socio-economic biomass metabolism.

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Input-Output Based Comparison of Household Energy Use and Greenhouse Gas Emissions for Canada and the U.S. **(Theme A 14)**

In Canada and the U.S. household consumption (i.e., use and associated production of goods and services) is responsible for over half of aggregate Energy Use and Greenhouse Gas (GHG) emissions. Only through a life cycle inventory of the entire goods and services supply chain can the sustainability of consumption be evaluated and dissected for effective policy design. In this regard, the use of input-output models in conjunction with consumer expenditure data is well established; research is proliferating in Europe, Australia and in some Asian countries. However, North-American empirical results are lacking and the implications of trade across the Canada-U.S. border are under-studied. This research addresses both gaps through a comparison of the sustainability of consumption in Canada and the U.S., using the most recently-available high quality environmental data for both countries. Energy use and GHG emissions are studied as a proxy for sustainability because they illustrate the evolution of our ability, or lack thereof, to decouple increased productivity from negative environmental impacts with regards to the key issue of climate change. This presentation compares the characteristics in monetary terms of consumption in Canada and the U.S and their associated environmental impacts. The input-output approach is leveraged to examine multiple facets of the issue, including: implications of trade; the relationship between energy mix and GHG emissions; the relationship between the structure of consumption and environmental impacts; and implications for environmental and economic policy. It is found for example that one-time consumption decisions (e.g., household size, personal transportation vehicle type) have the greatest environmental impact and can lock consumers into un-sustainable behavioral patterns. In addition, the fact that energy products (e.g., electricity, natural gas) have the lowest cost per amount of GHG emissions suggests arguments for the use of marginal tax strategies.

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Sustainable Housing for New Orleans: Modeling Urban Metabolism for Green Construction
(Theme B 15)

Assessing the near and long term reconstruction of New Orleans will require an understanding of the multiple needs of the city and the potential for multiple benefits. In the aftermath of Hurricane Katrina, a series of failed plans for reconstruction have defined a period of relative stasis and slow recovery. As a result, approximately one half of the city population lacks the means for return and adequate housing upon arrival. Recently, the city of New Orleans invited our research team to provide a guiding plan that prioritizes sustainable construction based on symbiotic relationships between the city's needs and the resources of the region. This request has resulted in the modeling of material and energy flows of New Orleans for the purpose of enabling a multi-disciplinary team to formulate an integrated suite of strategies for the reconstruction of the city. The entire lifecycle of the built environment has been considered with an emphasis on the employment training and job creation potential of developing cyclical material flows that did not previously exist. Disassembly of buildings, for example, has been carefully considered for the useful materials that may be harvested and the potential for job creation as part of a new set of closed material loops. Nascent instances of industrial symbiosis are of special interest in promoting firms that will hasten a quick, robust and resource efficient recovery. This presentation will describe the model developed to simulate the urban metabolism of the city and detail the final suite of strategies for a sustainable New Orleans. This project is part of a larger effort, requested by the City of New Orleans, to develop workforce development policies that can create job ladders for unemployed and underemployed residents in high performance building technologies, coastal restoration, and recycling.

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The Metabolism of Buildings: the Unique Spatial, Temporal and Physical Attributes of Contemporary Construction **(Theme F 33)**

An important challenge confronting industrial ecology is the development of practical expertise within diverse design and engineering disciplines. In fact, achieving progress toward the general establishment of working industrial ecologies may depend upon this development. Only then can realistic expectations of collaboration between industry and the industrial ecology community be realized. However, effective collaboration is partly dependent on articulating the idiosyncratic nature of an industry in terms that are both useful for the general discourse of industrial ecology and the work of that industry's designers, managers and workers. This articulation includes identifying distinctions and similarities between the industry and other industries and precisely outlining the salient features of processes and products of that industry. Ultimately, this articulation is intended to lead to the productive formulation of specific strategies that can be directly applied to the industrial activity and the design of its products. This paper contributes to this effort by offering a defining set of attributes that comprehensively articulate the character of resource consumption by the contemporary anthropogenic built environment. These constitutive attributes define the spatial, temporal and physical properties that govern the life cycle consumption of existing and new buildings. Each attribute has been synthesized through an examination of various sets of data including recent census surveys, real estate market studies, demolition permits, construction industry information and published building technology research. These attributes establish the context through which a working model of the lifecycle metabolism of buildings can be derived. Results are used to assemble a typology of resource consumption for an array of common contemporary building types. Finally, particular design strategies are reviewed for their role in providing society with resource efficient buildings.

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Strategies for Implementing WEEE Management Infrastructures: Technological and Business Challenges **(Theme E 28)**

Extended Producer Responsibility has been at the heart of European waste prevention and management policies over the last decade. In the context of the European Directive on Waste Electrical and Electronic Equipment (WEEE) (2002/96/CE of 27 January 2003), Portugal is presently implementing a national WEEE management system, which has resulted in the creation of 2 WEEE management societies. Based on this experience, it is discussed the premises for the strategy to be adopted by the WEEE management societies and analysed the main technologies and business challenges inherent to this process. The compliance with the WEEE Directive targets requires innovation at system and process levels. In fact, WEEE recycling can be achieved through the collection of WEEE and the subsequent interaction of distinct technologies, generally based on the separation of the materials that constitute the waste electrical and electronic equipments. In this context, the management of technologies for WEEE recycling, considering EEE composition, available infrastructures, WEEE production characteristics and its collection logistics are also examined. The financial flows on the WEEE management are analyzed and discussed in the context of the each intervenient responsibilities (from producers to distributors, users of EEE and collectors/transporters, recyclers of WEEE) including the transfer of the WEEE producers' responsibilities on their wasted products to the management societies. Finally, it is discussed how technological and system innovation associated to the WEEE Directive may generate business opportunities and represent a driver for environmentally improved product design.

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Tracking Consumption Impacts: Using Multi-Country Extended Input-Output Hybrid Model and Process LCA to Assess Local Emissions and Human Health Impacts of Globalized Production-Consumption Chains **(Theme A 6)**

Globalisation and the related growth in trade provoke environmental as well as socio-economic changes. There exists a need to shed a new light on international responsibilities for the environmental impacts of current consumption and related trade patterns, covering the relations between consumers in developed countries and affected citizens in emerging countries. This novel research method combines international IO tables and geographically-sensitive process LCA. Starting from the household final demand in the consumer country, a multi-country extended input-output hybrid model determines the physical flows of goods and pollutants required for the production, transport, consumption and disposal of goods (over the whole product life cycle) to meet this demand. The resulting emissions vectors are then converted to localized human health impacts by using environmental transfer and human exposure models. Preliminary results based on the specific case study of the globalized textile industry will be shown. Such a study is particularly relevant given the increasing separation of the sites of production and consumption and the growing share of developing countries in international trade. Indeed, while global environmental impacts and their related pollutants like CO_2 and global warming gases are slowly being considered by the international community, other types of environmental emissions which impact local health, related to atmospheric pollutants such as sulphur dioxide, dioxin or heavy metals, are still largely unaccounted for in international negotiations between industrialized and developing countries.

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Industrial Ecology - an Integrating Discipline Contributing to Sustainable Production and Consumption Systems? **(Theme D 24)**

Industrial Ecology is a rapidly growing scientific field, attracting especially environmentally interested engineers and natural science representatives. Sometimes it is also referred to as the Science of Sustainability. Looking at the historical development of the concept, it emanated mainly from the anticipated need to reshape the global industrial production system into a more environmentally benign functioning. In a wider perspective of a more sustainable development, however, it will be increasingly important to recognize the consumption side, something that calls for increasing attention to social aspects of development. It is widely recognised during recent years that (ecological) sustainability will not be reached without a stronger emphasis on and understanding of social aspects of development. A stronger attention to consumption would also foster an increased emphasis on (re)cycling and waste issues, since they are so interrelated with production and consumption systems. Another important aspect of the further development of Industrial Ecology is “natural” ecosystems functioning and development in co-evolution with industrial systems. Our industrial activities increasingly interfere with “natural” systems. In what way shall the science of Industrial Ecology interfere with and co-develop with the science of Ecology? Similar questions can be raised for a number of other neighbouring sciences to Industrial Ecology, sciences that already have their own more or less expressed agenda for sustainable development. In what way shall Industrial Ecology distinguish itself and/or interact with such scientific fields? In this paper, the emanating role of Industrial Ecology and its relations to other neighbouring sciences such as Ecology, Technology, Economy and Management will be discussed as well as its potential contributions and shortcomings in the work for a sustainable development.

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Which is a Better Material to Fulfill a Function?
(Theme A 4)

There are various possible materials (fuel) which are applicable to a function. For example, to fulfill the function of electricity, we can use heavy oil, coal, natural gas, waste paper, waste plastics, etc. Recycling is one of the ways to fulfill functions. The effect of recycling (e.g. CO_2 reduction) is evaluated by Life Cycle Assessment (LCA) or Life Cycle Inventory Analysis (LCIA) by comparing the systems with (= recycling process) and without recycling (= original process). The effect of recycling depends on the relative efficiency between an original process and a recycling process rather than the absolute efficiency of a recycling process. Under a conventional LCIA, one of the most effective uses of waste plastics is to substitute it for coal as fuel to heat water in a primitive way because the carbon content of coal is higher than other fossil fuels and it is easy for the recycling process to achieve the equal efficiency with the original process. However, we should judge the effect of the recycling process under a broader system boundary. For example, if natural gas is saved by recycling, the effect of CO_2 reduction in the conventional system boundary is calculated lower than the case of coal saving. However, we can use the saved gas for thermal electric power generation which generally has higher generating efficiency than coal fired electric power generation and, as a result, the total CO_2 reduction effect in the gas saving case under the broader system boundary can be higher than in the coal saving case. In this presentation, we will discuss about the method to know a better combination of a material and a function and will show case studies.

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Evaluation System Eco-Industrial Parks as Driving Infrastructures for Sustainable Urban Environmental Management **(Theme C 22)**

The symbiotic approach for developing and restructuring industrial estates is considered to be environmentally and economically efficient to meet the socially acceptable local growth with environmentally sustainable constraints. While symbiotic industrial projects are conceptually considered to bring economical and environmental benefits to both enterprises and surrounding stakeholders, their costs and benefits for the implementation have been difficult to be identified quantitatively, which prevented their practical application in decades so far. This paper provides the quantitative evaluation system for industrial symbiosis effects of eco-industrial parks which function as the driving centers for sustainable urban and regional management. Their empirical application for Kawasaki Eco town, Japan, as an innovative eco industrial development practice in North –eastern Asia is also presented. Firstly, an integrative regional spatial GIS?data base is designed and their scheme is established, which contains industrial activities and municipal environmental statistics such as waste emission and collection systems. Secondly, the technology inventory for re-utilizing waste water, utilizing organic wastes as energy sources, and taking the wastes as substitutional inputs for material processing and product manufacturing sectors are identified. Thirdly, the evaluation of the environmental effects of adopting symbiotic industrial system into the eco-town is developed. Finally, empirical application for Kawasaki eco-town is presented. The integrative system between regional data base and recycle technology inventories are provided as a Web GIS tool to promote the industrially symbiotic business among local enterprises. Environmental effects such as carbon dioxide emission reduction of for current industrial complex in eco-town are numerically identified as well as the effects for extensive policy scenarios.

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Discrepancy in Trade Statistics for Used Products and Secondary Materials (Theme A 3)

From aspects of the prevention of environmental pollution and the efficient utilization of resources, attention has come to be paid to the international used product and secondary material flows recently. In the evaluation of such international material cycles, trade statistics provided by each country gives useful quantitative information. However, trade statistics has a problem that there is sometimes discrepancy between the import (or export) data recorded in trade statistics of a reporting country and the export (or import) data recorded in the statistics of the partner country. In the case of used products and secondary materials, there is some possibility of becoming obvious of such discrepancy by the difference of unit between import and export data and by the change of item name for avoiding import restrictions. This paper clarified the discrepancy in trade statistics for used products and secondary materials using the statistics of various countries. As the factors that cause the discrepancy in trade, the follows was picked up: 1) the difference of item classification; and 2) the difference of unit; and 3) the change of item name; and 4) re-import and re-export; and 5) human error. We dealt with from 1) the difference of item classification to 4) re-import and re-export. As the results, the difference of item classification between countries was found by the examination of the detailed item classification for used vehicle. Next, the difference of unit, such as number and weight, in used tire and buttery was clarified. Then, the change of item name form read scrap to buttery was identified. The re-export from Hong Kong to China for iron scrap was grasped. Furthermore, we indicated total impacts of the above factors using the discrepancy ratio obtained from the import and export data.

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Modelling Farmers' Decision-Making on Land Use: An Integrated View on Socio-Ecological Systems (Theme A 9)

The development of integrated models that are able to simulate socio-economic processes, land use and socio-economic and ecological material and substance flows is crucial for analysing socio-ecological systems. This paper presents a model that helps to develop scenarios of regional rural socio-ecological systems depending on variations in both external framework conditions and internal decisions. The model presented combines an agent-based module (ABM) used to simulate farm households with a system-dynamic module that can simulate changes in land use and substance flows. The paper presents case studies of rural regions in Austria that are confronted with numerous environmental and social problems. The model can asses mid-term and long-term effects induced by changes in the farms' environment, such as changes in subsidies mainly regulated on a supranational (European) level, changes in agricultural policy, and changes in global market prices of agricultural products. The agent-based module analyses the decision-making process of each actor – i.e., each single farm – along a "sustainability triangle" in which each corner represents one of the core sustainability dimensions (social/ecological/economic). Three scenarios concerning global framework conditions are analysed: a trend scenario ("business as usual") is contrasted with a scenario that models impacts of an enforced globalisation of the economy and a third scenario that assumes a more sustainable development path. The results show that globalisation means a dramatic reduction of cultivated land because nearly 80 percent of farms will be forced to give up agriculture. In the "sustainability scenario", diverse production patterns are maintained and the intensity of agricultural production is reduced compared to the "globalisation scenario". Furthermore, the results of our case study show that although the European common agricultural funding system has important impacts on the economic performance of farms, national and regional policy

options are at least equally important in maintaining a vital and sustainable agriculture.

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Lessons about Sustainability and Sustainable Development Based on Four Historic Case Studies on Product Systems **(Theme D 27)**

Results will be presented from an interdisciplinary research project (2002-2006) , that focused on the process of (un)sustainability developments on micro-level and macro-level, for four products which can be considered as basic needs : bread, potable water, home heating and transportation by car, train or bicycle of people. We examined the environmental, social and economic aspects of the four products in the 'key-years' 1800-1850-1900-1950-1975 and 2000, using quantitative and qualitative analysis. Data retrieval has been based on national Belgian statistics, budget enquiries, literature, historical unpublished sources and environmental emission measurements on still existing ancient objects. Both the production and consumption phases have been studied and related with eachanother. On a micro level the environmental performance over the centuries has been determined per functional unit , following the life cycle approach. The cost price has been determined as a real price, expressed in number of working days needed to buy the product. An important social indicator has been the availability or consumption level for the individual consumer. On a macro level the total consumption of the Belgian society during the centuries for these products has been constructed , allowing us to show how the total societal environmental impacts have developed during the centuries. Interpreting these simultaneous developments , looking for similarities and differences, for the four product systems, both on micro and macro level, in the three dimensions of sustainability has created better insights in the concepts of sustainability and sustainable development for product systems.

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Process Integration for Sustainable Production Planning in an Agricultural Cooperative (Theme C 23)

The need to increase efficiency, improve environmental performance, comply with legislation and simultaneously preserve social responsibility are some of the key challenges to be faced by industry today and in the future. These challenges stem from both the low costs of labour and less constrained local production in emerging countries and the rapid development in consumer demand and questions concerning environmental and safety standards in industrialised countries. In addition, globalisation has connected markets through lower trade barriers and e-commerce and because the operating environment has changed, new approaches need to be developed to meet the challenges. Consequently, a new method based on approaches from process integration based on the pinch analysis combined with Operations Research methods is proposed as a systematic approach for characterizing process design options. By applying the methodology developed, decision support can be provided for the production process design of single companies and inter-company networks to improve resource efficiency. The case study of Pisco production in Chile analyses an agricultural cooperative producing Pisco, a brandy-like spirit, from a wine distillation process. In the harvest season several distributed facilities collect the grapes from the affiliated winegrowers and after removing the peduncles and maceration, the must is fermented and stored. In a second step throughout the whole year the wine is continuously distilled. The distiller's wash is the major source of emissions and is treated in an organic wastewater treatment system. For the reference company of the case study new options are discussed towards a more sustainable production process including all stakeholders of the cooperative.

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Developing Circular Economy in China: Challenges and Opportunities for Realizing Leapfrog **(Theme C 20)**

China is pioneering a new sustainable development model which has the ability to overcome current environmental and resource management problems, while achieving improvements in resource productivity and eco-efficiency. This model, formally accepted in 2002 and termed the “circular economy”, is understood to mean the realization of a closed-loop of materials flow in the Chinese economic system. Successful implementation of this model is seen as one way China can “leapfrog” past the environmental damages typically seen as economies industrialize. This paper introduces the development of the model in China, and presents the current situation of circular economy practice in China. The main focus of this paper is to describe current measures being implemented by decision-makers in China for the long-term promotion of a circular economy, including the formulation of objectives, legislation, policies and measures, so that the country can ‘leapfrog’ its way from environmentally-damaging development to a more sustainable path. The paper then identifies a series of barriers and challenges to the implementation of the concept In China. Finally, several conclusions about the future of the circular economy concept are drawn. Data were derived primarily from an analysis of secondary sources (i.e. previously published Chinese and English papers). Additional primary data derived from the main author’s personal involvement in several circular economy initiatives were also employed.

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Theory and Evidence of Displaced Production through Reuse and Recycling (Theme A 2)

Recycling of materials and reuse of products or their components is central to the theory and practice of industrial ecology. The idea of turning the wastes of a product system into resources for others lies at the heart of the industrial ecology metaphor. The need to 'close the loops' of an industrial society's metabolism is frequently taken for granted or demonstrated by assessing the environmental benefits of reuse and recycling. Such assessments often show that the environmental benefits of displacing other production processes, e.g. of primary material, are substantially larger than the benefits of avoided landfill or incineration. However, environmental assessments of reuse and recycling, whether based on models or empirical data, all share one fundamental problem: How do we know that reuse and recycling activities displace other production processes, and how do we determine which processes are displaced and to what extent? This is not a trivial matter since any proof of displacement needs to be grounded in counterfactual reasoning. An example would be: 'Virgin paper production would have been x tons higher if y tons of paper had not been recycled.' This presentation gives an account of the current theories of displacement in industrial ecology and reviews the existing efforts to substantiate these theories with empirical evidence. It is surprising and troublesome how little empirical work exists to date, given the importance of reuse and recycling in industrial ecology. The second part of the talk presents an empirical analysis framework of displacement and its application to several case studies.

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Common Imperatives in Peculiar Places (Theme D 24)

Even sympathetic commentators have pointed to “creative ambiguity” as the genius behind the phenomenally rapid and widespread acceptance of sustainable development. Today, with two decades of thinking and experimentation since the Brundtland Commission popularized the notion, we can be clearer about the core overall imperatives for progress towards sustainability, but we also know to respect the diversity of practical situations for decision making and action. Some of the biggest challenges now lie at the intersection of global imperatives and local differences: how to integrate a reasonably comprehensive common understanding of what is required overall for progress towards sustainability with proper attention to the particularities of case and context. For those considering industrial ecology initiatives, some of the most illuminating responses to this “common requirements and situated realities” challenge have been in applications of sustainability-based decision criteria in environmental assessment reviews. Notable Canadian examples include the approach taken by the Joint Review Panel for the Mackenzie Gas Project, now in the middle of its public hearings on the new proposal for gas gathering facilities and pipelines in the Mackenzie Valley. In July 2005, before the hearings began, the Panel notified the proponent and other potential hearing participants that it intended to “evaluate the specific and overall sustainability effects of the proposed project and whether the proposed project will bring lasting net gains and whether the trade-offs made to ensure these gains are acceptable in the circumstances.“ In support of this, the Panel commissioned a report on suitable criteria and associated frameworks for evaluations and decisions in the review. The presentation will examine how this report integrated a set of broadly applicable sustainability requirements with attention to the established regional expectations and concerns surrounding the proposed project. It will also consider implications for broader application, including possible lessons for the conception, design, review and approval of industrial ecology initiatives.

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Industrial Waste Exchange Program (Theme E 28)

The Technology Transfer Centre in Industrial Ecology (TTCIE), linked to the Sorel-Tracy College, is part of a network of 30 other technology transfer centers each evolving in its own field of activity in the province of Quebec. Its mission is to promote industrial ecology to industries through education and awareness activities as well as technical assistance and applied research projects. In the fall of 2005, TTCIE launched a new tool destined to support industry efforts in managing their wastes and divert industrial waste from landfills. This tool is the Quebec Industrial Waste Exchange Program (BRIQ) whose basic principle is to make the waste of one industry available to other industries for reuse as raw material or recycling. This material exchange occurs through a controlled access web site managed by TTCIE who encourages the exchanges by putting the appropriate industries in contact, by tracking the results of the material recycled and by soliciting new members to join. Companies must pay a yearly membership fee that includes unlimited access to the data, a plant visit to identify all input and output material, automatic e-mails informing the members of a new entry corresponding to their needs and monthly news. For an additional fee, TTCIE can assist members in characterizing their waste, in finding alternative disposal options and in developing value-added products from their industrial waste. To this date, over a hundred of different waste materials are available on the website (www.briq.ca). Several exchanges have been completed diverting several hundreds of tons of industrial waste from landfills. Two other tools are currently in development to complement the Exchange Program: an environmental gain calculation tool and an environmental technologies database.

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Copper Cycles in Germany: Stocks, Flows, Dissipative Losses and the Role of Recycling
(Theme A 2)

With natural resources becoming scarcer and ores becoming poorer, recycling is an important factor for the future availability of copper and other metals. For the same reasons, dissipative losses should be kept to a minimum. For a sustainable resource policy it seems thus necessary to quantify not only apparent consumption of metals, but also dissipative losses and describe the recycling performance at, for example, the national level. Such an assessment can be made when the stocks and flows are known in sufficient detail. Based on life-cycle data from 2000 and current statistical data on consumption, use, and waste management, a stocks and flows model for copper in Germany is being developed. Here, I present preliminary results for the magnitude of copper-containing flows, change in stocks, and the main dissipative losses for the German economic system. Based on these results different recycling quotas can be derived: an input oriented quota (share of secondary resources in production), an end-of-life oriented quota (fraction of total copper content being recycled at end-of-life), and a dynamic quota (share of today's production that will be recycled at its end-of-life). The latter one can only be estimated on the basis of scenarios describing product lifetimes, future collection and recycling technologies, and possible future legal obligations. Scope and explanatory power of the different quota definitions for the example of copper will be discussed.

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Collaborative Tools for Industrial Symbiosis Evolution **(Theme E 29)**

Industrial symbiosis (IS) refers to the evolution of industry from linearly optimized supply chains to an intricately woven web of resource flows similar to that of an ecosystem. Presently, tools available for IS systems design are for single users, such as a planners or facility managers. Successful examples of IS, however, favor evolutionary multi-collaborator models against master planned systems design. Even with information technology assistance, it is unrealistic from the perspective of western civilization to imagine a master planner capable of accounting for the intricacies of individual firms' interests. It is also problematic for any individual firm to entrust their decision making authority to a master planner. The success of tools and methods to catalyze or empower IS therefore hinges on their ability to provide collaborative mechanisms for cooperative optimization between multiple users. This presentation outlines existing and innovative features for IS design tools and how they may be successfully utilized in a multi-user cooperative design community.

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Biomass supply for a North American Biofuel Infrastructure (Theme A 10)

Future trends project increased growth in the transportation sector. Given our dependence on non-renewable resources and limited options for liquid fuels, renewable fuels are generating increased attention. Fuels produced from biomass (biofuels) have the potential to result in reductions of green house gases and air pollutant emissions over their lifecycle and to provide a more stable, domestically, and environmentally produced fuel supply compared to conventional fossil fuels. An understanding of biomass availability is crucial towards the development of a sustainable transportation sector. A number of studies have presented inventories of expected biomass availability in Canada and the U.S. This research examines and compares eleven studies on a scientific and engineering basis through a detailed evaluation of their assumptions and input parameters. We review and evaluate biomass availability in both countries, explain the variation in reported estimates, and determine reasonable ranges for estimates for a near-term time horizon. We analyse biomass supply from seven feedstock categories, including energy plantations, biomass residues, and agricultural crops. Studies report overall aggregate biomass estimates ranges from 44 to 1238 million dry metric tons (MT) for the U.S. and 3 to 515 million dry MT for Canada. Energy crops, agricultural residues, and forest and mill residues are predicted to be the largest contributors to total biomass supply. The wide discrepancies among biomass estimates are attributable to varied study approaches and assumptions and different time-frames under consideration. The most crucial parameters influencing future availability of biomass for energy will be the economics of biomass extraction and ultimately biomass conversion to biofuels, and competing uses of biomass in the economy. The results of this research provide a fundamental first step towards a systems approach assessing the feasibility of developing biofuel infrastructure in North America.

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Bayesian Material Flow Analysis (Theme D 25)

Among material flow problems there is a special class of problems in which one seeks to separate a target material component from a mixture. The separation mechanism may involve a variety of means including mechanical, chemical and biological, and the application may occur in many different settings including industrial systems and in nature. Examples would be; mining, recycling, materials purification, pollution scrubbing, bio-magnification, and bio-remediation. In this talk we review recent progress in developing a mathematical model to analyze these types of flows. The model assumes a binary separation process that can be described by two probabilities; the probability to correctly identify the target material “r”, and the probability to correctly identify the “not target material”, “q”. With these two probabilities, Bayes Theorem, and mass balances one can rigorously describe a probabilistic separation process that concentrates the target material in one output stream and dilutes the target material in the other output. This work has been applied to all of the areas mentioned earlier with generally good agreement with the available results in the literature[Gutowski 2006]. In addition, new work has extended this work to complex multiple flow networks including re-entrant flows [Albino 2006]. It is our intention to review the utility of this work in our talk, and to provide the mathematical details in a separate poster.

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Austria's Carbon Metabolism 1830-2000: Implications of the Agrarian-Industrial Transition
(Theme A 11)

Human-induced carbon emissions into the atmosphere are among the major drivers of global climate change. Humans cause carbon flows into the atmosphere mainly through two pathways. (1) Carbon-containing compounds are major outflows from socio-economic metabolism, above all caused by fossil fuel combustion. (2) Land use alters pattern and processes in terrestrial ecosystems, thereby changing their carbon balance. As a result, ecosystems may act as carbon source or as carbon sink. This study aims to gain a deeper understanding of the interrelations between these two processes by analyzing Austria's carbon metabolism during its transition from the agrarian to the industrial socioecological regime. We present a comprehensive account of the Austria's carbon flows from 1830 to 2000. We find that the transition from an area-based (i.e. biomass-based) energy system of agrarian society to the fossil-fuel based energy system of industrial society fundamentally alters Austria's carbon flows. In line with the forest transition hypothesis, we find that the transition to a fossil-fuel based energy system has allowed forests to recover from extremely intensive use in the agrarian regime, thus resulting in a considerable increase in the carbon density (C per unit area) of forests. Increases in agricultural yields obtained through agricultural intensification have resulted in a decline of cropland and grassland areas, thus resulting in a considerable growth of forested areas. Based on these data we argue that Austria's biota are a "fossil-fuel powered carbon sink". We discuss implications of these findings for climate policy and carbon accounting.

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LCA of Alternative Petroleum Refinery Technology: Gasoline versus Diesel Transportation Fuels **(Theme A 4)**

In this paper we compare alternative light duty vehicle powertrains and fuels building on work of M.Wang (Argonne's GREET model), M.DeLuchi (UC Davis), G.Keoleian (UMich), Sangwon Suh (UMN) and J.J.Marano (using DOE's refinery model). We extend the standard LCA methodology by comparing practical technology alternatives in fuels production: 1. rejection of carbon from heavy refinery gas oils using catalytic cracking versus 2. adding hydrogen with a hydrocracker unit. The cat cracker produces primarily gasoline and the hydrocracker produces primarily clean diesel fuel. Hence the choice of technology within a refinery determines the mix of gasoline and diesel fuel available for transportation. Since Europe and Asia are in the about the same refining situation as North America, that is all are seeking more distillate production relative to gasoline, there is not much opportunity for the produced mix of fuels to differ from the consumed mix of fuels through product trade. For our LCA of technology choice, we use a liquid fuels model developed for the National Energy Technology Laboratory, U.S. DOE, called Macro Analysis of Refining Systems (MARS). The MARS model has over twenty process steps and a full accounting of refinery carbon emissions. The sources of refinery carbon emissions are combustion of byproduct gases and purchased fuels, burn-off of catalytic coke, electric power generation, steam generation, steam methane reforming, and petcoke gasification. We supplement MARS with a vehicle stock-flow model and petroleum upstream carbon emission factors to complete the LCA comparison. We include sets of LCA cases depending on the source of hydrogen production for the refinery hydrocracker and the specific gravity and sulfur content of the crude oil feedstock.

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Application and Enlargement of the Scientific, Process Oriented Material Flow Analysis Method with Information Flow Analysis _ Application of the New Method to the Dynamic Route Planning in Truck Fleet Management of a Company towards Sustainable Resource Management
(Theme E 31)

In consequence of the rapid growth of resource consumption, unwanted byproducts caused by resource extraction (e.g. land consumption or unused excavated materials) or hidden, cost-intensive environment polluting material flows existing environmental strategies have to be reconsidered. Affected are companies, but also regions or towns, and in particular the corresponding decision makers. At the same time permanent increasing anthropogenic material stocks (e.g. constructions, boarding and paving) are built up. Finally all materials (with partially strong varying lifespan) either become -concerning the ideal case- secondary resources or -assumed that such materials can not be recycled- have to be deposited following pre-treatment. At present such resources are irrecoverably lost. For controlling and optimizing of such material flow systems the scientific Material Flow Analysis (MFA) method can be applied. Furthermore using this method potential environmental impacts can be identified prior their appearance and therefore can be prevented. At the same time today communication and information flow systems can not be considered decoupled of ecological questions like consumption and use of natural resources, rather a combination of those approaches is required. Nowadays within complex systems (e.g. companies, regions, towns) transformation, analysis, optimization and automation of processes are practiced using the Workflow-Management. By applying this method parts of those processes that can be realized informational are automated. The new method presented here -so-called hybrid method- combines information flow analysis and investigations concerning material flows and material stocks. This method based on the coevally generated computer-aided model combines the Material Flow Analysis method with the information based, middle-term Workflow

Management approach. A practical implementation demonstrates the influence of single sensitive information parameters within the Dynamic Route Planning in Truck Fleet Management of a selected company. It can be shown that even a small modification of such parameters can induce significant variations concerning several material flows.

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Systems Engineering for Sustainable Growth through Creation of an Eco-Industrial Park
(Theme E 29)

Understanding eco-industrial park formation requires a multidisciplinary viewpoint that includes systems thinking, industrial ecology, organizational dynamics, logistics, and supply chain theory. The most often referenced eco-industrial park found in Kalundborg, Denmark, serves as an ideal, and is typified by tight interdependency between industrial partners, green logistics, and closed-loop supply chains. But the planet is in crisis and can not afford to wait 30 years for more of these parks to emerge. Systems engineering has been found to be effective when bringing together stakeholders from diverse backgrounds and experts from multidisciplinary engineering and technical backgrounds to coordinate the creation of complex systems. This presentation summarizes the attributes of eco-industrial parks from a multidisciplinary perspective, and proposes a systems engineering framework, iFACE, for the formation of eco-industrial parks. The framework has been applied in an initiative in the industrial region around Verdal. Verdal is a small community in Norway, with a deep culturally significant tradition. The town has reinvented itself to keep abreast of changing times; moving from an agriculturally based economy to industrial region. The changes have been mostly evolutionary and unscripted until 1999 when a downturn in the business of the largest employer threatened everyone's welfare. Today, Verdal is one of the most stable and admirable communities in Norway. To remain that way, they are embarking on a new initiative using systems engineering methods to ensure sustainable growth. Progress has been made in mapping the industrial network and analysing the foundation for sustainable growth in the industrial park and the neighbouring communities. Efforts to create an eco-industrial park within the close of the decade will be described.

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Deriving Performance Measures from Integrated Land-Use and Transportation Models to Assess the Sustainability of Transport Policies **(Theme B 15)**

The emerging awareness of the need to modify urban growth patterns, both in terms of land-use and transportation, has motivated planning agencies in Canada, to develop comprehensive plans proposing the implementation of a broad range of policies aiming at achieving a more sustainable transportation sector. While sustainable transport policies and growth management plans are being developed in most Canadian urban areas, policy appraisal still suffers from a lack of formal evaluation tools and mostly relies on expert judgement. This situation has led to a renewed interest in Integrated Land-Use and Transportation models as instruments for assessing the impacts of land-use and transportation changes at different planning levels. Note that, the development and implementation of these models bear many challenges ranging from the behavioural soundness of different sub-components to computational and resource issues. Another challenge presented to integrated urban models relates to the level of “knowledge” that such models provide to decision-makers to understand the economic, social, and environmental impacts of different policy scenarios. In this context, the present research focuses on linking various “impact models” with the ILUTE (Integrated Land-Use Transportation and the Environment) model developed for the Greater Toronto Area (GTA) and deriving a set of performance measures that reflect the three levels of sustainability. The proposed presentation will discuss the link of the “environmental impact model” with ILUTE. This model will focus on quantifying a set of indicators reflecting resource consumption, environmental emissions and dispersion impacts of urban transportation in the GTA, using the results of simulated land-use and transportation scenarios generated by ILUTE. For this purpose, a set of environmental indicators is developed in addition to the analytical framework linking ILUTE with environmental sub-models (air pollution, noise, consumption of land and natural resources).

Spatial and temporal representations of the environmental indicators are also discussed.

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Bringing the Solar Energy Supply Chain Out of the Shadows: Assessment of Photovoltaic and Battery Related Heavy Metal Flows Using the MUIO-LCA Model **(Theme A 11)**

Fossil-based energy sources are contributing to disruptions in the Earth's atmosphere and natural systems on a global scale. Distributed photovoltaic generation and energy storage in batteries may offer an attractive alternative in certain applications. The installation of photovoltaic cells could reduce the burden placed on the electricity grid and provide a more efficient means of supplying energy in remote locations. Batteries provide could backup power when solar energy is not available. We use a mixed-unit input-output model to analyze the material flows and environmental releases associated with distributed photovoltaic cells and storage batteries. By combining material flow data with economic IO tables, the Mixed-Unit Input-Output LCA Model used in this analysis provides an innovative approach to estimating the entire supply chain material flows as well as economic and environmental impacts associated with the production of photovoltaic cells and storage batteries. Photovoltaics and storage batteries offer a low risk use for toxic heavy metals already in use throughout the economy such as cadmium and lead. Concerns about the toxicity of cadmium and lead have led to calls for discontinuation of their use, however large stocks of these materials are already available in the economy and additional supplies result from continued demand for zinc. Due to their presence together in ore, the material cycles of cadmium, lead and zinc are closely linked. Zinc consumption continues to increase due to its use in the manufacture of a wide range of products including construction beams, automotive parts and steel sheeting. Because of its low concentration in products, the logistics of zinc recovery are difficult. Few recycling pathways for zinc exist at present. The MUIO-LCA model for heavy metals used in this analysis is an important addition to the toolbox available to those interested in assessing the environmental impacts of technology options.

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LCA of CO_2 Enhanced Oil Recovery from the North Sea (Theme A 11)

We present a life-cycle assessment of a proposed Carbon dioxide Capture and Storage (CCS) project. The 'CO_2 value chain' consists of a gas-fired power plan in Tjeldbergodden on the Norwegian coast, an amine-based post-combustion CO_2 capture, pipeline transport to an off-shore oil platform in the Draugen field, and injection into the oil field for enhanced oil recovery (EOR). The project has been proposed by Royal Duch Shell and Statoil, who intend to realize this project in the near future. Shell Technologies has provided the technical data on which our calculations are based. The processing facilities required on the oil platform have been modeled in HYSYS. EOR results in a break-through of CO_2, which dilutes the natural gas which can be recovered, so that the gas is pumped back again into the field and does no longer provide platform power. There is a substantial power demand for the compression of the gas. We investigate two options: running the platform turbines on diesel or providing electricity from the gas-fired power plant using a sea cable. The entire system has two products: electricity from the power plant and additional oil from the platform. Different allocations are possible, depending on whether systems expansion, economic or physical allocation are used. Using CO_2 as a free input to EOR which has to be fetched from the capture unit, we find that EOR reduces the CO_2 emissions per sqm crude oil from 180 kg to 130 kg if diesel is used as platform fuel and 20 kg if electricity is used. This reduction seems at first sight surprising, but the hale production without EOR used as base case is energy intensive, because requires running the platform at low output.

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Heavy Metals Through the Years: Flows and Impacts (Theme A 6)

Effective management of and policies for heavy metals requires information about their use, flows, and impacts. Despite the toxicity and ubiquity of heavy metals in the United States there is limited data on their use. A mixed unit economic input-output (MUIO) model is constructed to provide estimates of the direct and indirect (supply chain) requirements for two metals, lead and mercury. The human health impacts of these requirements are then evaluated. The modeling and impact assessment is demonstrated for the uses of these metals between 1990-2004. The MUIO model is constructed by combining data from the United States Geological Survey (USGS) on the mining and manufacturing uses of heavy metals, the U.S. Bureau of Economic Analysis (BEA) of economic sector purchases, and toxic releases. Impacts of these flows are evaluated using the CalTOX model, which includes fate and transport modeling. The model is used to identify metals-intensive and high impact economic sectors. Changes in the use of these metals, such as the decreased use of cathode ray tube televisions and monitors, and mercury-free coal, are investigated and the impacts assessed compared to the status quo. Based on modeling results, recommendations for better management of these metals is proposed.

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A Game-theoretic Model for Increasing "Producer Responsibility": Refillables in the Packaging Market (Theme E 31)

Environmental policies in developed countries have taken tentative steps beyond the traditional focus on end-of-pipe or constraint-based waste disposal regulations, toward 'extended responsibility' for lifecycle impacts of manufactured goods. Current life cycle assessment tools used to assess the impacts of goods and services are not capable of describing the incentive structures that might explain the actions of different life-cycle players, thereby making truly extended responsibility policy difficult to implement. Game theory, on the other hand, allows investigation of policies that take into account the effects that stakeholders' environmental management decisions have on each other and the ways in which these interacting effects change the "playing field", so that we more realistically look for policies that promote the interest of the system as a whole. This paper applies the concept of game theory to a comparative analysis of refillable and disposable packaging under an extended producer responsibility program. Despite the dominance of disposable bottles in the US marketplace, this study suggests that refillable bottles may be more cost effective in the long run, provided that consumer return rates remain high. We show that government policies for promoting more sustainable packaging alternatives must be focused on encouraging bottler-consumer cooperation. This paper presents a simple model for testing the likely decisions of bottlers and consumers with and without government intervention, and finds that effective government strategies may include charging a packaging fee or tax at the point of production or enacting policies that reduce consumer cost of return, when the goal is to maximize an equitable distribution of benefits.

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The Role of Office Buildings in the Total Environmental Impacts of the Built Environment
(Theme B 19)

Buildings have a significant impact on the environment, but just how much has still not been researched to the fullest extent. Office buildings should account for a major part of all of the commercial buildings' environmental impacts because of the use of high amounts of construction materials, high demands for renovation and retrofit, and high relative energy use by building systems and occupants. Thus far several tools have been proposed to assess the life-cycle environmental impacts of buildings, but the measurement of the total impacts, especially the suppliers of the project delivery process and the integration of the use phase of the building with the other life-cycle phases has not been achieved. Moreover, the tools available on the market are not easily adopted by building designers and other professionals, and therefore fail to help buildings become less environmentally burdensome. Herein we report on research that has set out to change the way we design, build, operate and decommission office buildings. We synthesize existing knowledge in this field, and develop a decision-support tool (called BuiLCA) using U.S. data and practices for professionals involved in life-cycle design, construction and management of office buildings. Hybrid life-cycle assessment (LCA) techniques are used for this purpose. As a case study, we analyze the life-cycle environmental effects of a building on the campus of the University of California, Berkeley, and discuss the utility of information one can gain from the use of BuiLCA.

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International Flow of Recyclable Materials and the Prospects for Creating an Asian Regional Recycling Network (Theme C 21)

Japan has made a strenuous effort to develop a national recycling system in order to realize its vision of implementing a sound material-cycle society over the past decade. Other countries in Asia, facing similar escalating demand for resources and waste disposal in conjunction with rapid economic growth, have realized the importance of improving the efficiency of resource utilization, and have begun to develop their own recycling systems and policies. However, it has become apparent that nation-based recycling systems are being undermined by increasing trans-boundary movement of wastes and recyclable materials. This paper will argue that policy harmonization and the development of an Asian regional recycling network is necessary to solve these problems and enable Asian countries to jointly realize a sound material-cycle society. This paper will identify and analyze the problems that trans-boundary movement of wastes and recyclable materials pose for the development of recycling systems, and it will discuss how policies could be harmonized in order to achieve a regional recycling network.

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Network Brokerage in Facilitated Industrial Symbiosis (Theme E 29)

The practice of industrial symbiosis (IS) has shifted attention away from improving or optimizing the immediate environmental impact of single facilities, as typically demanded by traditional environmental management approaches, toward a more holistic view of the organization embedded in a network of exchanges. Such a network is multi-dimensional, comprising, at a minimum, material, economic, and ecological interactions. Recent research suggests that social interactions occurring within networks of exchange, including preexisting social ties between organizations and/or individuals, may influence the development of industrial symbiosis (Ehrenfeld & Gertler, 1997; Baas & Boons, 2004; Chertow & Lombardi, 2005; Ashton, 2006). This work demonstrates the value of understanding industrial symbiosis as a social, and material, economic, ecological, and geographic phenomenon. To contribute empirically to this perspective, this paper analyzes a number of facilitated regional IS networks in the UK on multiple dimensions. Using social network analysis (SNA) as a way to probe the emergence and change of these networks over time, we explore the influence of social ties on the development of these networks (Burt, 1992; Smith-Doerr & Powell, 2005). In addition, we explore the role of one primary broker organization, the National Industrial Symbiosis Programme (NISP), in influencing how the networks develop over time. Drawing from SNA as well as a diverse set of additional quantitative and qualitative data, we suggest a theory of brokerage for industrial symbiosis in relation to more traditional geographic, economic, and environmental explanations. This research has implications for understanding the social dimensions of practices that enable industrial ecology more generally.

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A Decision Support Tool for Traditional Industrial Systems' Eco-Industrial Transformation **(Theme C 20)**

Eco-industry tries to operate industrial systems environment friendly and mimic the way that natural ecosystems are running on. As a new pattern for industrial development, it attracts eyeballs from entrepreneurs and consultants engaging in sustainable industry development. However, to retrofit traditional industrial systems into new eco-industrial pattern is not easy. A lot of entangled factors, consequences and sequels have to be considered when making eco-industrial decisions. That is, the decision processes are complex for the volume of decision content usually unstructured, multiple objectives usually in conflicts and relations among decision points usually complicated. By characterizing and analyzing the features of eco-industry decision making problems, a decision support tool "Map of Eco-Industrial Decision Network" (MEIDN) is designed to structure and visualize the decision problems. Combining the utilization of MEIDN, the whole decision process is divided into four steps: investigating and analyzing, target architecture establishing, plan proposing, and decision making. Each step is illustrated within a case study of the eco-industrial decision making process of Jinxi Natural Gas Chemical Corporation Limited which is seeking an eco-industrial transformation. The case study validates the effectiveness of MEIDN.

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Architecture of Industrial Ecology – A Model for Education and Communication on What is Characteristic and Makes the Field Unique
(Theme G 36)

In this contribution, the emerging body of Industrial Ecology theory is organised in a unifying architecture. This basic architecture is illustrated in the form of a pyramid and built upon four basic layers (I-IV) or contexts respectively: (I) context of statements, (II) context of phenomena, (III) context of instruments, and (IV) context of basics. The architecture has its methodological basis in tools of philosophy. It is particularly based on a framework used in epistemology. This generic framework is conceptualised through a document analysis identifying certain issues that are prototypical for the Industrial Ecology community and literature. Due to its solid structure, the basic architecture is proposed for Industrial Ecology education and communication what is distinctive for the field. Despite its sound foundation, the architecture is easy to understand and simple to visualize. Hence, it is suggested as a model for Industrial Ecology education, particular for the communication on what is unique for the field. The architecture presented here has links to conceptual frameworks proposed by Vellinga et al. (1998), Weston and Ruth (1997), and den Hond (2000), among others. The aim is to stimulate the ongoing discussion on Industrial Ecology education and the dialogue what is key for industrial ecology, i.e. what are the features of its identity, and what makes this field of research unique compared to other scientific communities striving for sustainability. When considering a unifying “self-image”, scholars in the field will necessarily come across such educational issues. It is argued here that a proper method would be to analyse Industrial Ecology from an epistemological perspective, exposing the emerging body of theory and describing the contours of its scientific profile.

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Potential Energy Recovery and CO_2 Reduction from Organic Food Waste in Yokohama: Centralized or De-Centralized Biogas System Options **(Theme B 18)**

As a result of promoting sustainable use of biomass resources, utilisation of organic food waste has been highlighted for the purpose of better municipal solid waste management, energy recovery and CO_2 reduction in cities. Since biomass resources distribute broadly with relatively low concentration throughout the city region, it calls for a careful system design and analysis in order to maximise the benefits. The present study addressed the benefits of organic food waste utilisation by adopting bio-gasification plant in combination with sewerage sludge in Yokohama. By means of geographical information system with spatial datasets and numerical statistics, the analytical methodology was developed to estimate the spatial distribution of organic food waste and energy demand on individual building basis. Waste collection scenarios were illustrated to cover the organic food waste emission from food retailers, restaurants, hotels, schools and hospitals, which are targeted under the food recycling law, in addition to households. For waste transportation, the road network data was used to assume the route of organic food waste transportation. The analysis on eight collection scenarios and two system options (i.e. centralised and de-centralised collection and treatment) found that both options would potentially recover approximately 15000 ~ 33000 t-CO_2/year by their operation. Yet, the heat demand around the bio-gas facilities could limit their benefit as much as approximately 2000 – 5000 t-CO_2/year and 1000 t-CO_2/year for the centralized and the de-centralized options, respectively. The result highlighted the importance of the city scale spatial analysis and the demand-supply matching when such municipal solid waste management options are considered. The current methodology could be a useful tool to trigger a tailor-made discussion for urban environmental management practices.

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Theoretical Analysis of Subejective Choices in Eco-Efficiency (Theme A 12)

Eco-efficiency (E/E) is expected to be a tool to find a way to sustainability. Some expect E/E as an useful tool, though some are not or even dubious. one of the major criticisms stems from the difficulties of subjective decisions involved in E/E. The authors would like to discuss the theoretical structure of E/E from the view point of subjective decision. We propose a theoretical model to describe the subjective decision in E/E. The analysis shows that there is a possibility of Pareto improvement on the balance between environment and economy, however, the decision on the weighting of environmental problems or endpoints is not necessarily Pareto improvement.

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Evaluating Climate Projects on a City Level - a Survey of a Few Existing Methods and their Applicability Based on Experiences from Stockholm City Climate Investment Program (KLIMP) **(Theme A 13)**

The city of Stockholm's action programme to counter global warming was adopted in 1998 and has set goals, in both the short and long term perspective. The overall goal is to reduce the amount of greenhouse gases emitted per person from 4 700 kg of CO_2 – equivalents to 4 000. The goal was to be achieved by 2005. To further the implementation, certain projects have received governmental funding in a nationwide programme. The Stockholm part of the programme 2005-2008 consists of ten different projects in energy, traffic, information/communications and mobility. The projects range from investments in new technology to information to change citizens' behaviour. Industrial Ecology, at KTH has received funding a scientific evaluation of the projects. The overall goal is to verify the effects of the projects and their role in achieving their part of the boundary programme's goals and to facilitate the information exchange between the projects. The main scientific goal is to investigate and develop methods for measuring and comparing effects of different types of local actions and methods for adding these results on local/regional program level. The paper will describe how the projects are being evaluated on both the project level and on the organisational level and what unique characteristics differ from the national or global level. This will include a survey of three different methods used today; the green house gas protocol; the draft version of ISO 14 064 and the method primarily used to evaluate the Stockholm's previous action program. The scientific questions of the paper are; How do the surveyed methods handle the problems when comparing, evaluating and adding the effects of different types of projects together? What are the current methods strengths and weaknesses? What special demands does the city level perspective add and how can these demands be met?

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Can Environmental Taxes Promote Sustainable Consumption? An Analysis for the Netherlands
(Theme A 14)

Consumption contributes to environmental load both directly (i.e. environmental pollution that occurs after a product is purchased) and indirectly (i.e. environmental pollution that occurs during the production and distribution of a product). In earlier work, we have analyzed the environmental load due to private consumption in the Netherlands for a large number of product categories, linking data on consumer expenditures to environmentally extended input-output analysis. This allows to determine the environmental impact of changes in consumption patterns. Given the role consumption plays with respect to environmental pollution, a shift towards a more sustainable consumption pattern is often considered a condition for a sustainable development. Changes in the level and the composition of consumption are driven by various factors, including disposable income and prices. Therefore we estimated price-elasticities for consumption categories. This allows to calculate changes in the consumption pattern as a result of price changes due to the implementation of environmental policy instruments such as environmental taxes, tradable emission permits and command and control and the resulting changes in the direct and indirect environmental impact.

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Development of a New Simulation Game for Teaching Material Flow Management in Higher Education **(Theme G 36)**

In order to be able to realize material flow management successfully in the operational practice, a sound methodical background is necessary. Additionally, several competencies for recognizing and solving problems as well as for accomplishing and communicating of solution alternatives are essential. Pure knowledge transfer does not suffice for the transfer of these competencies. However, simulation games are suitable to obtain a strong, individual examination of the topic through a playful approach at a very realistic level. For this reason a new simulation game considering material flow management has been developed and used successfully in higher education at Pforzheim University (Germany). Within this simulation game, students act in different roles of a virtual enterprise of the automobile supplier industry. The aim is the formulation of relevant optimization potentials based on material flow analyses. In addition to the transfer of theory and the application of material flow analyses, the accomplishment of role and goal conflicts is also a central point. Compared to conventional simulation games the parameters of the production system are initially unknown and must be worked out by the players firstly. In the following game rounds these are primarily conflicts of goals, e.g. between ecology and quality, which must be handled. The practical use of the simulation game in higher education has led to a very deep comprehension on part of the students for the use and the potentials of material flow analyses in the practice of producing enterprises. Furthermore, a high engagement was noted during and beyond the game rounds also regarding not technology-oriented study paths. Therefore, the simulation game is suitable in a high extent for use in higher education.

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The Use of Agent-Based Models in Developing Transition Instruments for Industrial Networks - a Focus on Management of Uncertainty (Theme D 26)

In previous work published by the authors, an analytical framework and a modelling tool for analysing the evolution of industrial networks with explicit consideration of agent behaviour was presented. These models provide insights and understandings of the complexity of agent interactions within an evolving environment. These tools can be used to explore the potential consequences of new technologies, alternative business strategies or the introduction of new governmental instruments on the sustainability of the networks. However, the models are based on a large number of environmental, behavioural and relational parameters and variables, each associated with considerable uncertainty. Furthermore, the nature of the interaction between these variables is uncertain. Uncertainty can not be ignored in network analysis, because it is an intrinsic property of the future and highly affects agent behaviour. However it also creates an almost infinite range of possible futures thus making the evaluation of the effectiveness of transition instruments in the design of sustainable industrial networks impossible. The large number of interactions and feedback loops between different network variables makes it impossible to evaluate the effects of their uncertainty a priori, and a more rigorous methodology is required to evaluate and compare suggested transition instruments. This paper presents a discussion on methodologies for the exploration of key uncertainties (of both a technical and valuation nature), in the particular context of these systems, where the implicit characteristics of agents and the network as a whole dominate decision making.

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Assessing Impacts of Megaquarry Development in the Cement Industry through Spatial and Transportation Network Analysis **(Theme A 1)**

The most recent measures of cement production estimate 97.4 million metric tons are produced annually in the U.S., and global production is estimated at 2.1 billion metric tons. In an increasingly globalized economy, cement is shipped long distances to meet demand. Other quarry products used in construction, such as aggregates, have moved toward large-scale centralized production sites, or “megaquarries”. Despite the cost of transport, these heavy low-value materials are moved long distances, even crossing oceans, to reach markets. Cement production facilities, usually a co-located limestone quarry and cement plant, face many of the same barriers to siting and incentives for increasingly centralized production as aggregate quarries. This research examines the impact on sustainability, focusing on transport related energy consumption, of a trend towards megaquarry production in the cement industry. A number of factors affect potential cement megaquarry sites; the quality and extent of mineral resources, barriers to permitting, and accessibility to markets. These factors are modeled using tools from geographic information science including overlay analysis to determine feasibility of siting, and transportation network analysis to analyze a site’s accessibility to markets and the cost and energy consumption associated with distribution. Results compare the cost and energy associated with supplying the region from an optimally-sited megaquarry facility with the costs and energy resulting from an optimized distribution scenario for the existing cement production facilities in the region. Modeling results show megaquarry development in the region is economically and geologically feasible, but not favorable from the perspective of transport-related energy and its associated environmental impacts. Additionally, the study shows that evaluating distribution networks for economic costs rather than energy efficiency results in different optimal scenarios. Since companies generally will choose to reduce economic costs, this suggests cement will be transported sub-optimally from an energy efficiency perspective.

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Optimal Clothes Washer Replacement Policy for Households (Theme B 19)

The energy efficiency of the average clothes washer in the U.S. improved by 88.4% from 1981 to 2003. Replacement of old vertical-axis washers with new horizontal-axis washers results in decreased operating costs, both environmental and economic. But replacement also results in one-time financial and environmental impacts from purchasing, manufacturing and disposition. A Life-Cycle Optimization (LCO) model developed to quantify this trade-off and determine optimal replacement intervals for residential clothes washers. Life-Cycle Inventory (LCI) and Life-Cycle Cost (LCC) profiles were defined for each model year clothes washer from 1985-2020. These profiles represent four life-cycle phases of a washer. In addition to characterizing the material production, manufacturing and assembly, use, and end-of life management phases of the washer, the optimization model also includes key parameters that represent water heating and clothes drying. Decisions for washer replacement are dependant on the technology and equipment age of a household's water heater and clothes dryer. These two system components expand the boundaries and complexity of the optimization. The results of the LCI and LCC studies showed that the use phase of the washer's life cycle accounts for 96-99% of energy, carbon dioxide emissions and water use, but just 61%-86% of total costs over an anticipated 20 year life. From an energy or carbon dioxide emissions perspective, any average washer, regardless of model year, should be replaced with a new horizontal-axis washer in 2006, 2011 and 2016. In addition to a base case that seeks to model the typical American household, four alternative scenarios were examined. Alternative simulations were run with electric water heater instead of gas, cold water washing, line drying, and different energy price forecasts. The replacement patterns for washers will be contrasted with other product systems including refrigerators and automobiles to draw general conclusions about optimal product replacement from environmental and economic perspectives.

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Evaluation of Eco-Efficiency Indicators in Iron and Steel Industries in Nepal (Theme C 20)

Many iron and steel industries have been significantly contributing to Nepal by producing infrastructural products as well as also exerting burden on environment. The concept of measuring eco-efficiency and its application is not still implemented, thereby, loosing opportunity of creating more value with less possible environmental impacts. The eco-efficiency of two different industries, Hama iron and Steel Industries Private Limited, Simara, manufacturing iron rod and Rajesh Metal Crafts Limited, Jeetpur, manufacturing black and galvanized iron pipe, both located in southern part of Nepal, have been evaluated. This study evaluated energy intensity, material consumption, water use, and waste intensity using provision of eco-efficiency indicators empirically, within production boundary of these industries. Eco-efficiency of manufacturing iron rod industry was quantitatively analyzed that revealed, productions were increasing and creating more value with less consumption of energy. Consequently, material consumption, water use, and waste generation have been decreased gradually for past five years (2001 to 2005). Whereas eco-efficiency evaluation of manufacturing black and galvanized iron pipe industry indicated differently as energy consumption was being increased and uneven for same duration (2001 to 2005). However, material consumption, water use, and waste generation trend have been decreased. The anticipated results of this research provided tangible feedback to decision level to formulate better option for wise utilization of energy, material, and water with less possible ultimate wastes that ensure sustainability in industrial ecology of these industries. It is recommended that evaluation of eco-efficiency should be implemented in iron and steel industries. It is high time to augment the concept of eco-efficiency in existing industrial policy and to link to existing legislation concerned in Nepal.

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Assessment of Aqueous Cleaning Process by Integrating Life Cycle and Risk Assessments
(Theme F 34)

In metal-degreasing processes, many kinds of chemical substance are used as cleansing agents and they can cause various adverse effects on human health and the environment. Substitution of aqueous cleansing agents has been recommended because the emission of VOCs from conventional cleaning processes with organic solvent can be reduced. However, some components in aqueous cleaner have aquatic toxicity and they are discharged directly to a river in some cleaning sites. We analyzed and evaluated both global and local impacts of a typical aqueous cleaning process by integrating life cycle assessment (LCA) and risk assessment (RA). Local adverse effects associated with the use of hazardous chemicals were evaluated by RA, while potential impacts on the global environment through the life cycle of cleansing agents were evaluated by LCA. We compared several alternatives including aqueous processes with different types of wastewater treatment, and solvent processes with and without improved chiller. The LCA results indicated greenhouse gas emission from the solvent process with improved chiller was as much as that from the aqueous process. The RA results of the solvent processes showed inhabitants' health risk around a cleaning site due to released solvent was sufficiently low. We also found there existed a considerable ecological risk due to surfactants when an appropriate wastewater treatment was not installed to aqueous process. This means substitution of aqueous process for solvent one causes another adverse effect. This study revealed selection of cleansing agent and design of process based on risks, not on hazards, is important and integrating LCA and RA is effective to assess various aspects of environmental impacts originated in cleaning processes. In addition, we raised an important issue about the management of global and local impacts: how to deal with trade-off problems between different aspects of environmental impacts by interpreting LCA and RA results comprehensively.

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Function Model to Support Supervising Environmental Impact and Chemical Risk by SME (Theme F 35)

Small and medium sized enterprises (SMEs) are far behind in supervising environmental impacts and chemical risks originated in own processes from large enterprises, because they have many difficulties in performing assessment, and generating and selecting alternatives due to the lack of skill, information and funds. In this study, a function model to support the engineers at SMEs performing risk-based design with rigorous risk assessments by using their available knowledge is proposed. The function model consists of activity models revealing the activities of the engineers on site and the functions of practical support tools, and thus promotes the voluntary management of chemical risks at SMEs. Referring the proposed function model, practical support system for SMEs can be implemented. In Japan, SMEs constitute a significant fraction of metal-part manufacturers and chlorinated agents are widely used because of its inexpensiveness, nonflammability and great ability as a cleansing agent. Although there is the vogue in assembly industry to adopt a voluntary policy eliminating halogenated chemicals from the whole production processes, alternative chemicals or processes may increase chemical risks and cause unforeseen adverse effects without appropriate assessment of each process. Actually, we found that the substitution for chlorinated agents does not always reduce the risks under each individual condition, and the administrative conditions depend on each enterprise. Therefore, technically and economically practicable alternative fulfilling individual conditions should be proposed on the basis of the results of risk assessments even in the voluntary management of chemical substances without governmental regulation. The proposed function model has mechanisms enabling engineers on site to take into account individual conditions in risk-based design. In order to verify the practicability of risk-based design by SMEs, case studies of metal-degreasing process designs using process information obtained through investigation of actual sites was performed.

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An Analysis of the Differences in Results between Regular and Hybrid LCAs Illustrated by the Example of Fuel Cell Vehicles (Theme A 6)

One of the more general things we have learned from LCA case studies on mobility is that the bulk of the environmental impact comes from driving the vehicle. Recent hybrid LCA studies have rendered a completely different conclusion: the bulk of the impact comes from the production of the vehicle. In our presentation we will address this contradiction by identification of the main factors leading to these different results and we will try to shed some light on future use of these tools next to each other. We will use the case of Fuel Cell powered vehicles to illustrate our analysis.

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Environmental Bottlenecks of a Renewable Based Hydrogen Economy (Theme F 32)

Though a hydrogen economy is generally propagated as a “clean” alternative for current fossil fuel based economy the question is how “clean” this hydrogen economy truly may be. Even if renewable energy sources would be used to produce hydrogen a number of environmental issues would remain whilst additional new problems might occur. In a hydrogen economy, hydrogen and water are emitted. The emission of molecular hydrogen has been the topic of a debate on the possible effects of these emissions, specifically on stratospheric ozone and on climate change Furthermore, the production, transport and use of hydrogen as a fuel requires a whole series of new processes, materials, products and infrastructure which all will have an environmental impact of their own. In this presentation we will describe a future hydrogen economy that is purely based on renewable energy sources and address the following question: What environmental bottlenecks can be expected in a hydrogen economy based on renewable energy sources ?

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Inter-Regional Waste Input-Output Model and Best Available Eco-efficiency of Regional and Nationwide Economy **(Theme A 6)**

The Japanese law provides that most waste of municipal and industrial origin should, in principle, be treated or disposed of within the region in which it is generated. On the one hand, this principle is closely related to NIMBY issues and may be supported from a social point of view. On the other hand, the principle might cause economic and/or environmental loss because a regional concentration possibly improves eco-efficiency of waste management. For example, there are 25 eco-industrial parks (EIPs, or eco-towns) working in Japan in September 2005, and they are expected to promote regional economies or improve regional eco-efficiency (EE). Their promotion should be consistent with “the establishment of a sound material-cycle society” that is one of the most important recent environmental policy objectives promoted by the Government of Japan. Because the expansion of EIPs inevitably needs to collect waste and recycled materials from over a wide area, it is desirable that an analysis of regional EE is carried out based on a framework which takes account of EE in other regions and nationwide EE. Thus, the inter-regional waste-input output (WIO) model is an outstanding analytical tool for regional EE; the model properly takes into consideration the intra- and inter-regional flow of goods, waste, and recycled materials. By applying the inter-regional WIO model and its extension based on the method of linear programming to Japanese data, we study the current status of regional EE, and explore the extent to which regional and nationwide EE can be improved. In addition, a method for decomposing a nationwide EE into regional EEs is developed and the contribution of each region to the nationwide economy is discussed.

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Combining Material Flow Analysis with Data Envelopment Analysis to Evaluate the Performance of Stages in Material Cycles (Theme A 1)

Over the past years, an increasing number of material cycles have been analyzed in order to identify the major potentials to reduce resource consumption and waste emissions. Less attention has been paid so far to the systematic evaluation of cycles on national, regional, and global scales, which is essential to bridge the gap between academic analysis and policy design. At the same time, various industry and government organizations have developed performance indicators for specific materials and stages in the life cycle. However, these indicators often lack an explicit system definition and are therefore not transparent, making it impossible to compare performances across stages, materials, and spatial and temporal scales. In this paper, we introduce a set of indicators based on a generic system definition for anthropogenic metal cycles. The indicators measure resource efficiency in metal production, manufacturing, use, and end-of-life management. A data envelopment analysis (DEA) is used to compare and evaluate performances of different stages among different countries. Data Envelopment Analysis (DEA) is a linear programming based technique often to evaluate the efficiency of a set of decision-making units. DEA was first developed by Charnes et al. (Charnes et al., 1978) in 1978 has mostly been utilized as a benchmarking and performance evaluation tool. In order to apply DEA to the performance evaluation of MFA systems, the decision units were chosen to be identical with processes. The proposed performance criteria are defined through a common system structure so that they could also indicate the overall efficiency of the system, while emphasizing the relative importance of the different stages. Steps and implementation of the proposed methodology are discussed using a case study of the anthropogenic iron cycle.

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The Global Metabolic Transition – Empirical Evidence of an Ongoing Process (Theme A 1)

The global metabolic transition is a hypothesis derived from historical evidence on changes in social metabolism during industrialization. In this paper we present a first comprehensive global assessment of socio-economic material and energy flows at the country level in a time series from 1910 - 2000. Our data are based on the international standard methodology for material and energy flow accounting (MEFA) and build on international statistical databases (e.g. FAO, IEA , Forest Resource Assessments). These MEFA accounts include humanity's full carbon flows, thus for the first time creating an integrated database of socio-economic biomass, fossil-fuel and industrial-process based carbon flows. Our results demonstrate that the magnitude of carbon flows resulting from human energy and material consumption increased dramatically since the 1960ies, thus pushing the Earth's carbon system into an historically unprecedented situation. Currently, almost half of the global population is still making a living within a pre-industrial or agrarian mode of subsistence, characterized by a per capita level of energy input (including food, feed, fibre and technical energy) of less then 50 GJ/cap/yr of which less than 30% are fossil fuels. One billion people hardly uses any fossil fuels, i.e. less than 10 GJ/cap/yr. One billion people lives in an industrial mode of subsistence characterized by a fossil energy consumption of more than 100 GJ/cap/yr covering more than 50% of total energy input. We will analyse global patterns and historical trends of growth of material and energy consumption in relation to economic development in different world regions. The paper will discuss the implications of the globally still ongoing transition from the agrarian to the industrial society for the future of global material and energy flows and if we should expect a decoupling of economic growth and energy/material flows in Southern Countries.

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Actors' Incentives for Improved Wood Waste Management. the Role of Regulation and Market Interactions (Theme D 26)

Material flows of, for instance, plastic, wood and metal often contain hazardous substances. During waste treatment, these contaminants are either emitted to the environment, or else they end up in residue products or recycled materials posing future pollution concerns. Their presence also limits possibilities for beneficial use of the waste. Separation of contaminants is often suggested as a way to address such problems. In this presentation, I will discuss how driving forces such as regulation and market interactions have influenced actors' incentives for separation measures in Sweden. The discussion will be based on a doctoral thesis, where the management of contaminated wood waste from the building sector was studied. After collection and sorting, this waste is processed to a profitable biofuel for actors in the Swedish energy sector. It can be argued that the government could, through regulation, play an important role in motivating development of separation measures. Despite that such regulations have been introduced, however, the studied actors still often have low incentives for such measures. A lack of steering mechanisms such as communication and supervision seems to have neutralized the inherent pressure from regulation. Instead, the results show that customer requirements are the main driving force for actors to improve their practice. In order to obtain sufficient profitable fuel for heat production, however, actors in the energy sector often practice inconsistent enforcement of quality requirements. As a consequence, actors in the building and waste sectors do not experience any strong pressure for separation of contaminants from their customers. In fact, this practice seems to have counteracted legal pressures for separation, due to present customer-oriented business management.

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Three Fundamental Approaches to Assess Human-Environment Systems with Respect to Sustainable Development: Strength, Weaknesses and Synergies of Scenario-Based Assessment, Impact Assessment and Systemic Assessment Approaches **(Theme D 27)**

A major challenge in dealing with the guiding principle of sustainable development is to define appropriate normative reference states or system conditions. This requires developing and applying appropriate methods for assessing and subsequently improving human- environment systems (e.g. a regional anthropogenic metabolism, an industry, or an industrial process) with respect to this guiding principle. Many scientists as well as legal and private institutions have dealt with the question how to address this issue. However, a comparative evaluation of different fundamental approaches to assess human- environment systems with respect to sustainable development and of their theoretical bases is still missing. Three of these approaches are: the scenario-based assessment approach, the impact assessment approach, and the systemic assessment approach. The scenario-based assessment approach constructs a desirable future state of a system as reference point and subsequently assesses the current performance of the system in comparison to this state. The impact assessment approach focuses on impacts of system processes and their significance for sustainable development. Finally, the systemic assessment approach analyses the function, structure and context of a system and assesses how well these system characteristics are shaped according to system theoretical principles. Although these three approaches overlap in various aspects, a prototypic differentiation is important to reveal basic strengths and weaknesses of the approaches, and to effectively use their synergies. This paper presents a comparison of the mentioned approaches with respect to the underlying epistemological background, the methodologies used, their applicability to different scales of human-environment systems and their compatibility with other approaches.

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Integrated Structure and Materials Design for Sustainable Concrete Transportation Infrastructure **(Theme F 33)**

The development of new transportation infrastructure materials is often disconnected from design, construction, and system management. Problems originating from this separation have resulted in using high performance concretes in Colorado and California bridges since 2000, which proved to be highly durable in laboratory development but have exhibited poor durability since field deployment. Impacts associated with reduced infrastructure sustainability due to this disconnect between material developers and infrastructure engineers can be widespread and long lasting. To bridge this separation, a new integrated structure and materials design (ISMD) framework is presented which ranges from nanometer-scale materials development to kilometer-scale infrastructure system management. This framework is unique from previous design paradigms in two ways. First, strong engineering linkages connect material development, structural design, and system management, providing a comprehensive design platform across varying length scales. Stemming from this integration, sustainability concepts are introduced in all phases of design, construction, and management and evaluated through an LCA feedback loop. Links between infrastructure engineering processes and LCA are made through material compositions, innovative structural service life models, and system sustainability indicators. To demonstrate the potential impact of this feedback framework from infrastructure material development through system management, a unique cement-based material, engineered cementitious composite (ECC), is investigated for the specific purpose of improving bridge infrastructure sustainability. While many “green concretes” focus on incorporating industrial wastes, they often ignore the associated negative impacts of reduced material performance on infrastructure durability and overall life cycle performance. Using ISMD, green ECC has been designed to be 500 times more ductile than normal concrete. This is accomplished while using industrial wastes to replace 75% of virgin feedstock but remaining highly durable, thereby cutting bridge

maintenance activities by 50% over a sixty year service life and resulting in significant reductions in material consumption and infrastructure user costs from traffic delays.

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Comparative Study on Processes and Outcomes of Eco-industrial Park between Japan, China and Korea **(Theme C 22)**

In recent years, attention for eco-industrial park (EIP) development projects has grown enormously in many countries. EIP is consistent with the notion of cleaner production, circular economy and industrial ecology. It is believed that a well planned, functioning EIP has the potential to both benefit the economy and substantially relieve environmental pressure in and near the location of its development. Over the past decades, the development of integrated economic, social and environmental benefits in the eco-industrial park (EIP) has been achieved almost everywhere. A number of Asian countries had formal EIP projects or initiatives. In China, an initiative to promote EIP development under the central government's leadership was established in 1999. Up to now, there are 17 National Eco-industrial Demon-Parks (NEIDP). Korean EIP project consists of 3 phases, and each phase needs 5 years from 2005. In1997, the Japanese government approved a Zero-Emission project to reduce waste from Japanese household and industrial activities by using waste as resources for neighboring industries. This project is called as "Eco-Town" and 26 eco-towns are in operation. In order to promote the development of EIP in Asia and analyze the experience in different countries, this paper makes international comparison of EIP on the aspects of establish process and outcomes special between Japan, China and Korea at national and industrial park level. There are many differences on the management and operation system of the EIP between the 3 countries. The detailed information of the process and main outcomes in the 3 countries is given and analysed. Through comparison, this paper concludes the common success factor and the deficiency of each country and the experience could help the development of EIP with each other.

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Two Years in Review – EcoStar Accomplishments (Theme G 36)

The Devens Enterprise Commission has continued its efforts to embed industrial ecology into its award winning EcoStar environmental branding and achievement program. In the two years since ISIE last met in Stockholm, the Commission has been recognized for its efforts, received funding to hire a part time EcoStar Coordinator, developed its programs and grown its membership to include 26 members. <Workshops> EcoStar hosted nine workshops, which drew an average of twelve attendees. Topics covered: • Energy Conservation • Cooperative Purchasing • Water Conservation • Lean and Green Manufacturing • Energy Efficiency A Real Turn On • EcoStar Nuts and Bolts • Ensuring Environmental Compliance • Sustainability in the Small Office <Program Benefits> Member benefits were expanded to include: • Two hours of dedicated technical assistance per month to assist with members' efforts to decrease their environmental impacts. • Expanded business networking and mentoring opportunities by designating time during workshops and adding quarterly Roundtable events to promote the exchange of information and facilitate partnerships. • A bi-monthly electronic newsletter to keep members informed of announcements, information exchanged during workshops, and upcoming activities. • A resource library that provides support materials related to the EcoStar Standards. • The EcoStar Exchange, an online tool that members can use to facilitate the exchange of reusable materials. <Grants> DEC received a technical assistance grant from DEP to evaluate the feasibility of a permanent collection facility for residential household hazardous products and wastes (used oil, electronics) from businesses classified as a very small quantity generator. Jessie B. Cox Charitable Trust awarded a $40,000 grant (over two years) to the DEC to support the development of the Devens Eco-Efficiency Center, which will further expand the benefits provided through the EcoStar program with increased educational and technical support services. Devens joined ICLEI Local Governments for Sustainability's Cities for Climate Protection Campaign. <Devens Eco-Efficiency Center> Mission: To create a resilient and stable

business community with companies that are ecologically sensitive and economically viable for Devens.

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Applying IE in a Business Environment, Transforming Environmental Innovation into Business Practice (Theme E 31)

This presentation will discuss strategy, methodology and tools necessary to partner with representatives of private industry, commercial organizations and government agencies to build a "business case" for transforming IE theory, research and conclusions into fundamental business practice. Problems to be solved/addressed include framing IE strategy, programs and solutions to resonate with the business and financial objectives of executive management, using the formal and informal processes of business decision makers and gate keepers, applying the tools and methodologies of financial decision making to demonstrate credibility, the use of pilot programs to overcome apprehension of corporate risk taking, implementing IE solutions so they fit the framework of traditional management systems, the art of selling and marketing to the target organization, leveraging the organization's global supply chain, how to adapt proposals to reporting systems and performance metrics, building cross functional relationships and partnerships, defining and defending your business case, understanding the target organization's corporate culture and tolerance for risk, and creating strategic partnerships and alliances to bring new ideas to senior management. We must also consider how environmental advantage as a branding tool is influencing corporate reputation, management systems and competitive advantage in an increasingly competitive global market place.

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LCA and LCC of Biomass for Fuel **(Theme A 10)**

Industrial biotechnology has a large sustainability potential through the use of renewable resources, potentially leading to reduced usage of fossil resources and CO_2 emissions. In view of the CO_2 reduction targets agreed upon in the Kyoto protocol, bioethanol has become an attractive option for one energy application, as a fuel. However, relatively little research has been done on the analysis of the entire life cycle of bioethanol for this application. Therefore, a complete and systematic study is urgently needed to assess the entire life cycle of bioethonol, including different options of resources for bioethanol production. This study presents a comparative life cycle assessment (LCA) on gasoline as fuel, and with two types of blends of gasoline with bioethanol, all used in a flexible fueled vehicle (FFV). The life cycle of bioethanol includes agricultural production, second generation ethanol production, blending ethanol with gasoline to produce E10 (10% of ethanol) and E85 (85%), and finally the use of E10 and E85 in a FFV. The feedstocks of ethanol production focus on corn stover and sugarcane. The results of the analysis show that the allocation methods to be applied consistently are essential for outcomes. A life cycle costing (LCC) for the fuels has been conducted, indicating that outcomes depend very much on the oil prices assumed. The overall evaluation of these fuel options depends on the importance attached to different impacts, and the cost-effectiveness of other options to reduce climate changing emissions. Furthermore, technological improvements are of great importance in both agriculture and ethanol production. LCA as it stands now cannot capture all relevant discussions as on land use, quantitative potential, etc. More important pathways to expand the analysis will be indicated.

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Relationship Between Urban Morphology and Sustainability of Water Supply Systems (Theme B 16)

Sustainability has become a political, economic and demographic issue. As more and more people live in cities, urban areas tend to grow faster than they can be controlled. The intent of this paper is to study which consequences the layout of one city, based on its density, can have on the sustainability of its water supply system. Three different layouts for a generic city of 500,000 inhabitants have been considered, from very dense to a sprawled city (that is the closest to the present reality). The layouts of these water supply systems were modelled to estimate the cost of each of it over a few decades. The conclusion is that the more sprawled the city is, the more it costs to build the network (3 to 5 times more expensive between the dense and sprawled model), and more energy (i.e., bigger pumps) are needed to service the area. And these costs are exclusive of any maintenance costs. These findings imply that a sprawled city is far from being sustainable. Furthermore this issue is not only of a water supply issue, the entire urban infrastructure system is of concern: electricity, transportation, roads, etc… This is why this paper is part of a bigger program that affects urban sustainability. Unfortunately, the North-American way of life is dramatically unsustainable. Whereas countries such as western European countries, manage to promote reasonable densities, most North American cities need to improve their public transit systems to influence public transition away from private automobiles.

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The Use of MFA and the Ecological Footprint in Sustainable Development Policy Making: A Case Study of Northern Ireland **(Theme A 13)**

Northern Limits, the first MFA and Ecological Footprint (EF) of Northern Ireland was completed in March 2004. This research represented the first application of industrial ecology principles such as MFA to the provision of an evidence base for development of sustainable development policy in Northern Ireland. Northern Ireland first sustainable development strategy was published in May 2006. A strategic objective is 'to become more resource efficient' with key targets of 'stablisation of the Ecological Footprint by 2015 and reduction thereafter' and the 'Northern Ireland economy will achieve 85% resource efficiency by 2025.' The strategy was developed with stakeholder involvement, however this process did not include MFA and Footprint practitioners. Therefore uncertainties arising from the application of MFA at a sub-national level and data availability and quality on the setting, measurement and monitoring of key targets were not considered in the policy making process, in particular the use of a resource efficiency target instead of MFA derived indicators. Northern Limits II, completed in September 2006 involved updating the MFA and Footprint; a data gaps, needs and quality assessment; a sensitivity analysis of the Footprint and a Footprint standards audit of the project. The project identified the next steps required to address the issues relating to data availability and quality and the use of MFA and EF in providing a measurement and monitoring framework for the strategy. The use of MFA and Footprinting in sustainable development policy making and monitoring of its implementation is an ongoing process in Northern Ireland. This is currently being supported by a programme of capacity building for stakeholder groups in resource accounting and the establishment of the Sustainability and Resources Institute as a focal point for collaborative research which bridges science and policy in the field of resource management and sustainable development.

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Opportunities for Industrial Ecology in Power Generation Supply Chains **(Theme A 6)**

The electricity industry is extremely important to both our economy and our environment, and we would like to be able to examine the economic, environmental and social policy implications of various future power generation scenarios. Using a new enhanced input-output life-cycle assessment model, we can look at the results of these scenarios and look for opportunities to incorporate industrial ecology throughout the power generation supply chain. In previous work, we had built upon the existing framework of an aggregate model – the Economic Input-output Life-cycle Assessment (EIO-LCA) tool – by adding data about the electricity industry. We added information to the Power Generation & Supply sector of a 500-sector model of the U.S. economy by splitting up, or disaggregating, this single sector into 24 additional sectors, each representing a specific construction or operation portion of the electricity industry. For each of these disaggregated sectors we created a supply chain – what the sector purchased from the other 500 sectors in the economy in order to produce its output – and a set of emission factors which allowed calculation of the environmental impact of the sector's output. With all the new sectors inserted into the existing economic input-output framework, we built future generation scenarios – each with a specific mix of generation types and investment in future technologies. We looked at the economic and environmental results which included not only the top-level emissions, but the impacts from the entire supply chain. With these results we were able to search for sectors with important supply chain connections and report on opportunities for environmental synergies. This paper reports on the basic environmental and economic results and the more complex life-cycle supply chain analysis of the electricity industry. The method, if not the results, should be expandable to beyond the U.S.

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Assessing the Impact of Urban From on Livability and Sustainability (Theme B 19)

The livability and sustainability of two very different urban forms in Portland, Oregon will be assessed using analytical tools. Portland is chosen because it illustrates typical patterns of morphology and suffers problems that are common to other North American regions. Portland also actively addresses regional problems with progressive planning strategies The neighbourhoods chosen differ in the sense that one is considered to represent conventional urban design and the other is considered to be among the state-of-the-art in sustainable urban design. INDEX indicators, developed by Allen et al. (2001), will be used to facilitate a livability comparison. These indicators yield helpful measures of comparison such as density, land-use mix, connectivity (the extent to which street design promotes walking and biking) and transit accessibility. To facilitate the comparison of designs in terms of biosphere impacts, Economic Input-Output Life Cycle Analysis (EIO-LCA) will be used and supported by mass and energy balances. EIO-LCA calculates the direct energy and emissions associated with the product or service in question, as well as indirect effects involved in the supply chain over the entire life-cycle. The work presented will be part of a PhD thesis project comparing a representative sample of conventional neighborhood designs to those that are regarded as progressive in terms of livability and sustainability. The goal is to uncover the designs that promote livability while minimizing environmental costs and to suggest potential modifications to transportation and land-use development methods in order to help practitioners create more sustainable urban forms.

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A Regional Industrial Symbiosis Methodology and its Implementation in Geneva, Switzerland
(Theme E 29)

The Agenda 21 for the Geneva region is the results from a broad consultation process including all local actors. In 1999 more than 43 entities including private consultants and companies, NGO's, political parties and local communities presented their how vision for a more sustainable region. Due to intense information process, the article 12 stipulated that « the State facilitates possible synergies between economic activities in order to minimize their environmental impacts » thus opening the way for Industrial Symbiosis (IS). An Advisory Board for Industrial Ecology and Industrial Symbiosis implementation was established in 2002 involving relevant government agencies in a participative approach. Regulatory and technical conditions for IS are studied in the Swiss context. Results reveal that the Swiss law on waste do not hinder by-product exchanges compare to the EU policy. Technical factors including geographic, qualitative, quantitative and economical aspects are detailed. The competition with waste operators in a highly develop recycling system is also tackled in a participative approach perspective. Their importance as key third party agents and experienced collaborators on sustainability requirements is recognized in the project. Launch in 2004, the IS project develops an empirical and systematic method for detecting and implementing by-products synergies between industrial actors disseminated throughout the Geneva region. Database management tool for the treatment of input-output analysis data and GIS tools for detecting potentials industrial partners are constantly improved. End 2006, 19 companies from 10 industrial sectors are involved in the first step of the project and potential symbiosis for 17 flows (including energy, water and material flows) are currently studied for implementation. High participation rate in the early stage due to high environmental awareness will facilitate communication for involving more industrial partners in the future.

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Dynamic Material Flow Analysis of Steel Scraps in Asian Countries: Case studies for Japan, South Korea, China and Taiwan **(Theme A 8)**

The total crude steel production in Asian countries was 500 million t in 2004, which accounted for 47% of the total crude steel production in the world. There have been a large demand of steel scraps in Asian countries, and Japan has been the main exporter of steel scrap. Change in steel scrap demand in Asian countries in the future has been of great interest because it may change the material flow of steel scrap drastically in the world. In this work, the chronological data about steel production, scrap consumption, and their import and export in the 20th century in Japan, China, Korea and Taiwan were collected. Then we analyzed the amounts of inhouse, industrial and obsolete scrap generation. In the case of Japan, where the detailed data about lifetime distribution of products and collection rates of scraps from end-of-life products are available, a population balance model was adopted to calculate the obsolete steel scrap generation in the future. It was estimated that the total steel scrap generation in Japan would increase up to 45 million t in 2015. On the other hand, in the case of Korea, China and Taiwan, a logit analysis was applied to estimate the total steel accumulation in the future. Then, we calculated the obsolete steel scrap generation based on the leaching ratio from the total accumulation. It was forecasted that the obsolete scrap generation in Korea would continuously increase, which would exceed the current amount of the scrap import in around 2010. The total accumulation of steel in China was estimated as 2.26 billion t in 2003. Taking several influential factors into consideration, it was speculated that the steel scrap import of China would not drastically increase because the increase in scrap demand would be covered by in-house scrap generation.

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Introducing Industrial Ecology to Broader Audiences (Theme G 36)

Industrial ecology as a discipline is a complex combination of sciences, engineering, social sciences, and business. The impetus for research in industrial ecology is the changing consumption patterns underlying our society and the impacts this consumption has on the environment. Yet, often the research regarding these connections between consumption and impacts is not communicated to broader audiences so that they may make educated decisions in their day-to-day activities. The Green Design Institute at Carnegie Mellon University designed an outreach program to communicate our research results to students interested in pursuing engineering. The program introduces students to concepts of materials flow analysis, life cycle analysis, and input-output analysis, and using these tools to address critical problems in energy, water, and infrastructure systems. The program has served to accomplish two goals. First, the program educates participants about the connections between consumption and environmental impacts. The participants recognize how industrial ecology tools can be used in their own personal decision-making to reduce this impact. Perhaps most importantly, the program educates future leaders of the need to consider issues in a wide, systems perspective, where multiple disciplines influence outcomes. Second, the program has assisted the researchers to more effectively communicate research results and implications. Within the industrial ecology discipline, the program materials have served to inform how to teach concepts at the undergraduate and graduate level. Outside the discipline, the program has helped researchers identify misconceptions that must be addressed initially, and recognize the level of understanding of basic materials and energy sources that must be explained. Most importantly, the program has required researchers to translate research results into relevant scenarios applicable to everyday decision-making. We will present an overview of the program and its evolution, and the lessons learned by researchers during development and refinement.

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Enabling Carbon Offsets at Point of Purchase for E-Commerce Deliveries (Theme A 14)

Many studies have estimated fuel use and carbon emissions for various transportation or delivery modes. Air transport is the most resource intensive and polluting, followed by truck, rail, and water. Studies have noted that significant reductions in retail delivery impacts might be possible if consumers were enabled to make informed decisions about delivery mode at time of purchase. We will overview a collaborative project with Carbonfund.org, a non-profit retailer of carbon offsets - a fee paid that in exchange is used to support carbon abatement projects (e.g., green power). We have developed robust estimates of carbon emissions for delivery of various products and modes. This has resulted in a computer tool used to market carbon offsets to prospective e-commerce companies' "shopping cart" systems. In addition to the cost of purchased products, a line item estimating the carbon emissions and associated offset cost for the selected delivery mode will be added, as well as links to information on those impacts. These are generally on the order of 1-5 cents per transaction. Carbonfund certifies these companies' deliveries as CarbonFree™ with stickers on boxes used by the retailers. The initial customer of this project is a socially responsible online bookstore company, Better World Books. The long-term goal is to develop an application programming interface (API) to be used with the Postal Service, FedEx, and UPS so that shipping rates and carbon emissions can be estimated for transactions at point of purchase for all e-commerce companies in the US, further enabling the dissemination of carbon emissions information to all consumers. We will give the current status of the project, total tons carbon reduced or offset, other companies using it, how many customers went on to buy further offsets, etc.

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Towards Resource-Oriented Wastewater Management in Urban Areas: MFA-Based Evaluation of Scenarios for the City of Hamburg
(Theme B 16)

The current paradigm for wastewater management includes the removal and transfer of wastewater from its point of origin to a centralised treatment station. Subsequently, energy intensive end-of-pipe treatment steps are in place in order to remove organic pollutants and nutrients from the water before it is discharged into surface waters. However, within the scope of the discussion about the need for sustainable development, calls for a paradigm shift are requiring to increasingly look at the energy and resource efficiency of our current wastewater system. In particular the link between sanitation and food production is crucial since agriculture is dependant on mineral fertilisers, which are produced in an energy-intensive way and use fossil resources like phosphate rock. Thus, instead of removing nutrients from the wastewater to protect water sources, best use should be made out of the potential resource wastewater. Different technologies aiming at the recovery of nutrients from wastewater exist or are currently under way. These range from centralised system e.g. for the recovery of phosphorus from sewage ash to decentralised and source-control systems including, for example, the separate collection of the nutrient-rich urine. However, there is a need to assess and evaluate those technologies from a systems analysis point of view in order to be able to support decisions regarding the implementation of resource-oriented water systems in urban areas. This study presents the application of a Material Flow Analysis (MFA) in order to evaluate five wastewater management scenarios for nutrient recycling applied to the city of Hamburg, Germany. The scenarios were selected in such a way that different scales of source separation were included. Their resource efficiency was assessed by analyses of flows of nutrients (N, P, K, S, C) from the households to agriculture as well as energy analyses of the urban water and wastewater system.

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MFA as a Tool for Resource-Oriented Sanitation in Ethiopia – Case Study of Arbaminch (Theme C 23)

The Millenium Development Goals call for halving the number of people who don't have access to safe water and sanitation. In order to achieve this, enormous efforts are required to develop and implement appropriate water solutions in developing countries especially in urban areas. However, too often infrastructure planning neglects a holistic view on the whole urban system and its agricultural hinterland and therefore does not allow a sustainable use of our resources. For example, common drawbacks of sanitation systems in developing countries include: - Reliance on water for transport of faecal material where water is a scarce resource. - Insufficient treatment of wastes which results in the pollution of precious water sources. - Neglecting the natural nutrient cycles where soils are depleted and in need of organic matter and nutrients. Therefore, this study used a material flow analysis of the water, waste and wastewater system of the city of Arbaminch in Ethiopia, in order to show which constraints and potentials exist for the implementation of a sustainable sanitation system. The current situation of water and waste management was assessed, a material flow framework established and water and nutrient flows were analysed after an extensive data collection. The analysis highlighted not only the current pollution due to the uncontrolled disposal of wastes, but could also identify some possibilities for a change towards more sustainable sanitation. Possible improvements include measures such as the separate collection of urine and subsequent use as a fertiliser as well as the combined treatment of faecal material with organic wastes for the production of soil conditioner. MFA proved to be a useful tool not only for addressing the sanitation situation but also to help improving agricultural production and food security.

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Environmental Impact and Added Value in Forestry Operations in Norway **(Theme A 9)**

The forestry sector is experiencing an increasing demand for documentation on environmental performance. Previous studies have revealed large differences both due to location and forestry practice. Reliable information on environmental performance for forestry operations in different regions should thus be obtained. This paper presents a case study on forestry operations in Norway where both environmental performance and value added in the selected operations are assessed. This is done using a hybrid LCA approach. Main results including sensitivity analysis are presented for a set of 4 impact categories. The value chain assessed includes the processes from planting of forest to the delivery of logs to a downstream user.. The environmental impact is mainly caused by logging, transport by forwarders and transport by truck. These three operations are responsible for approximately 85% of the total environmental impact. The impact on value added and total costs are more evenly distributed. The sensitivity analysis reveals that the difference in the worst case scenario and the best case scenario is more than a four-fold in environmental impact. The single most important factor is the transport distance from pile to factory. The results show that the environmental impacts from forestry operations in boreal forests probably are underreported in earlier studies.

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Characterization of Carbon and Nitrogen Fluxes in Crops Grown for Energy (Theme A 10)

It is commonly assumed that bio-based alternatives are environmentally preferable to petroleum products. Life cycle analyses have shown that materials derived from biomass are renewable and have fewer greenhouse gas emissions in comparison to petroleum products, but have environmental impacts resulting from heavy reliance on fossil fuels, fertilizers, and chemicals. The debate surrounding bio-based products often focuses on energy use and climate change benefits, sometimes neglecting thorough analysis and quantification of deleterious impacts resulting from non-point nutrients and pesticides. A key question surrounding bio-based products is whether improvements in climate change potential are offset by increased risk of water quality degradation. A framework has been developed using Monte Carlo Analysis to characterize carbon and nitrogen fluxes in corn, soybean, and switchgrass agriculture for a variety of management schemes and conditions. While large data sets exist to check the validity of the corn and soybean models, switchgrass is not currently cultivated for economic purposes and little is known regarding environmental impacts or best management practices of switchgrass monocultures. The results of this study quantify non-point sources that are often neglected in LCA due to uncertainty. Use of Monte Carlo Analysis generates results that are applicable to larger regions and can inform policy decisions regarding establishment of regulatory guidelines and best management practices.

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A comparative European Study on Environmental Pressures Arising from Consumption and Production Patterns Employing Environmental Input-Output Analysis
(Theme A 6)

A comparative study is presented employing environmental Input-Output Analyses (eIOA) and shift-share analysis in order to investigate production and consumption patterns and associated environmental pressures (namely, Global Warming Potential, Acidification Potential, Tropospheric Ozone Forming Potential, and Direct Material Input) in 8 EU Member States. The study has been launched by the European Environment Agency in relation to two broader EU-policy areas: (1) Sustainable Consumption and Production Pattern, and (2) Sustainable Use of Natural Resources. The overall objective is to provide an EU overview on consumption and production patterns and related environmental pressures. A further objective is to identify priority areas for policy action towards SCP. Production patterns are investigated with regards to main point-sources of direct environmental pressures. Consumption patterns are investigated in order to identify products with the highest production-cycle-wide environmental pressures along their chain. Further, it is investigated whether European countries are shifting environmental burden abroad through increasing imports of raw materials and semi-manufactured goods. The study confirms for the EU countries that provision and demand for basic needs, such as housing, food, and transport, constitute priority areas where innovations towards Sustainable Consumption and Production Patterns are mostly needed. Further, it identifies improvement potentials and gives recommendations for policy action.

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Modelling Industrial Ecosystems as Populations of Agents, Strategies and Artifacts (Theme D 26)

Modelling industrial ecosystems as populations of agents, strategies and artifacts Complexity theory is a systems approach which has brought new life in many scientific disciplines where a more typical reductionist approach has proven insufficient. Complexity proponents see systems as not only conducting exchanges and adapting to their environment, but also as convolving with it. Since complexity theory seems an ideal approach for the study of change, it has also been used by scholars involved in the transition of the existing industrial system towards sustainability. The first part of our paper reviews the interpretation of complexity theory in the literature of human-technology-environment systems. We show that complexity (which is not a single theory but encompasses more than one theoretical frameworks) has been used for different purposes (description, prediction etc.), in a variety of contexts (industrial ecology, ecological economics, ecological modelling, integrated resources management, etc.) focusing on several properties (connectivity, diversity, efficiency, fitness etc.) In the second part, we present a higher level analytical framework for the study of industrial ecosystems which is based on Axelrod's and Cohen's view of complex systems. More specifically, we describe an industrial ecosystem as a population of three elements (agents, strategies, artefacts) on which the processes of variation, interaction and selection take place. Our framework, in contrast to existing collections of static single case description, can be used as a way of analysis of the dynamics of industrial in a comparative manner.

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Historic Patterns of Anthropogenic Iron Stocks
(Theme A 7)

A recent study of the historic U.S. iron cycle revealed that the per-capita iron stock incorporated in products in use increased throughout the 20th century, until it reached a plateau of about 11-12 tons around 1980. This finding led to the hypothesis that iron stocks reflect the degree of industrialization: per-capita iron stocks in agrarian societies are insignificant, they increase during industrialization, and they remain on a high level in societies that transform into information or service economies. In this presentation I test this hypothesis by analyzing and comparing the historic iron cycles of six industrialized countries in different continents. In-use stocks of iron are calculated using historic data for production, trade, and waste generation, and estimations for product lifetime distributions. Patterns of iron stocks in use are analyzed in terms of presence and level of saturation. The stock pattern approach is further placed into the context of literature regarding the intensity of use approach. The analysis of patterns of in-use stocks is highly relevant for improving long-term forecasting of iron and steel demand and scrap supply in emerging market economies, and therefore has significant implications for industry and government policy.

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What is the Real Resource Potentials of Secondary Resources? (Theme A 7)

Rapid economic growth in some Asian countries stimulated the trades of secondary resources, including both scraps and secondhands. These emerging trades have drawn a strong attention from the viewpoint of their “Toxic Potentials.” We have to acknowledge “Toxic Potentials” accurately so that we can avoid it turning into a real problem. However, we also recognize “Resource Potentials” in secondary resources. Here we focus on Resource Potentials. We introduce new measures for the Resource Potential of secondary resources not in terms of “Price.” The proposed measures must be useful for long-term sustainable material cycle management. We listed and organized the factors which affect Resource Potential. So many factors, which are not well reflected in the market prices, are related to the properties of natural resources, which are substituted with the secondary resources of our concern. Once these factors were listed and the indices are formulated for each factor, the values for each element were calculated. For example, niobium does not contribute much to the Resource Potential of secondary resources in terms of the depletability, since its resource is abundant. However, its risks for short-run supply disruption is high because the niobium is dominantly supplied by one huge mine. This fact increases the Resource Potentials of the secondary resources containing niobium. In this study, a small case study for e-waste was carried out. Market sees the resource potential of e-waste mainly in copper, and a little in precious metal. However, in this case study, currently often unrecovered minor elements, like as tantalum in capacitor, contribute a lot to the e-wastes’ Resource Potentials. In this sense, the elements should be more encouraged to recycle and necessary technologies should be developed.

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Material Flow Analysis of Plastics and Metals in the Japanese Economy Based on WIO-MFA
(Theme A 2)

At the 2004 ISIE meeting, two of us presented a new method of MFA, termed the WIO-MFA (Nakamura and Nakajima, Mater. Trans. 46-12, 2005), which represents an integration of MFA with the Waste Input-Output (WIO) model (Nakamura and Kondo, JIE 6-1, 2002). The WIO-MFA is a physical version of WIO-MFA that is fully consistent with the mass balance principle. At the 2004 meeting, we presented the basic concepts of WIO-MFA and its application to the flow of quantity metals in Japan. Metals and plastics constitute the largest part of industrial materials that are used for machines and appliances. This presentation is concerned with extended application of the WIO-MFA to cover plastics such as thermosetting resin, polyethylene (low density), polyethylene (high density), polystyrene, polypropylene, vinyl chloride resin, high performance resin, and other plastics. Besides tracing the flow of metals and plastics among different sectors and fabrication stages of the economy, the model will also be used to estimate the metal and plastics composition of process waste and end of life products, and to trace the input origin of the material composition for specific products such as cars and appliances.

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Waste Input-Output-MFA of Quantity Metals with Explicit Consideration of Smelting Processes and By-Production of Precious Metals **(Theme A 2)**

At the 2004 ISIE meeting, two of us presented a new method of MFA, termed the WIO-MFA (Nakamura and Nakajima, Mater. Trans. 46-12, 2005), which represents an integration of MFA with the Waste Input-Output (WIO) model (Nakamura and Kondo, JIE 6-1, 2002). The principle of mass conservation is at the core of any MFA. With this regard, the conventional input output analysis (IOA) is flawed because of its neglect of the flow of waste. The WIO-MFA is a physical version of WIO-MFA that is fully consistent with the mass balance principle. Furthermore, the WIO-MFA provides a formal mathematical definition of “materials’’ that guarantees the avoidance of double counting (counting of a given “material’ more than once), which seems missing in the literature on MFA. At the 2004 meeting, we presented the basic concepts of WIO-MFA and its application to the flow of quantity metals in Japan. In the last presentation, the use of quantity metals was investigated in detail, but its production process (transformation of ores and scraps into metals) was not. This paper is concerned with explicit consideration of the production process of metals within the framework of WIO-MFA. Verhoef et al (JIE 8-1/2, 2001) point to the importance of properly considering the interdependence of metals such as the production of rare metals as by-products of quantity metals in LCA. Great emphasis is placed on the smelting processes (electrolysis) of copper, lead, and zinc, including the by-production of precious metals such as silver and gold, and the recovery of zinc from steel arc furnace dusts. Some simulation results will be shown on possible effects of a sudden reduction in the demand for certain quantity metals on the supply of precious metals.

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Construction of the Methodology for Integrated Assessment Based on Cost-Benefit Analysis and Applicability for Strategic Environmental Assessment **(Theme D 27)**

In this study, the methodology for integrated assessment based on CBA (cost-benefit analysis) was proposed with a view to application to SEA (strategic environmental assessment). The characteristics of this methodology are to provide information for a strategic decision-making process, to integrate environmental, social and economic impacts into a single indicator in monetary value, to estimate life-cycle inventories concerning global impact categories, and to reflect residents' preferences to valuation of local impact categories. Local impact categories are converted into monetary value using conjoint analysis and global impact categories are converted into monetary value with the coefficients estimated by EPS. In the case study of MSW (municipal solid waste) management system in Kawasaki City, the following three options were compared: the status quo, where plastics waste were collected and incinerated along with combustibles; the alternative I, where plastics waste was collected separately and directly landfilled; and the alternative II, where plastics waste was collected separately and recycled in blast furnaces. The following impact categories were established, i.e., global warming, resource depletion, human health, landfill capacity and costs. Life-cycle GHG (greenhouse gases) emissions and fossil fuel consumptions were estimated, and urban air pollutants emissions were converted into local residents' health damages. The results showed that recycling of plastics waste had effects on reduction of GHG emissions and fossil fuel consumptions, while the status quo was supported from the viewpoint of landfill capacity and costs. The result of integrated assessment suggested that, if the social benefit of implementing separate collection itself was recognized, the alternative I or II was the best from the viewpoint of CBA. If the social benefit of implementing separate collection itself was not recognized, the status quo was judged to be the best.

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Examining the Environmental Soundness of Growth of Consumption and Technology in Japan **(Theme A 14)**

Today's material welfare has been achieved at the expense of consumption of finite resources and generation of environmental burdens. Over the past few decades the volume of global consumption has grown dramatically, while at the same time technological advances have enabled products with greater efficiencies. These two directions of change: consumption growth and technological advance, are the focus of the present paper. Using quantitative measures for these two factors, we define a new indicator: "eco-velocity of consumption", analogous to velocity in physics. The indicator not only identifies the environmental soundness of consumption growth and technological advance, but also indicates whether and to what extent our society is shifting towards sustainable consumption. This study demonstrates the practicability of the indicator through a case study in which we calculate the eco-velocities of Japanese household consumption in two years: 1995 and 2000. The rate of technological advance during the periods concerned is quantified by applying the embodied carbon dioxide emission per yen of product. The results show that the current growth rate of Japanese household consumption is greater than the rate of technological advance to mitigate carbon dioxide emissions. We also calculated the eco-velocities of household consumption in term of other environmental burdens including wastes emissions. The eco-velocities at the level of individual commodity groups are also examined. Considering changes in the import and export patterns in Japan, the sources of changes in eco-velocity for each commodity are identified using the method of structural index decomposition analysis.

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Complex Adaptive Systems and Industrial Cluster Development: How to Support the RDA?
(Theme D 26)

Around the world, Regional Development Agencies (RDAs) have the responsibility to sustain the socio-economic and ecological prosperity of their region. RDAs deal with forces both internal and external to their influence. Industrial parks emerge as a result of distributed decision-making processes. Crucial decisions are made by a variety of independent agents. Thus, RDAs must address the questions: (1) what are the options for the future development of my cluster (2) what is effective policy, what will make my cluster "tick" (3) what effect on cluster size, character and prosperity will my actions have? Complex Adaptive Systems are defined as dynamic networks of many agents (species, individuals, firms, nations) acting in parallel, constantly acting and reacting to what the other agents are doing. The overall behavior of the system is the result of a huge number of decisions made every moment by many individual agents. Industrial networks fit this definition, they are complex adaptive systems. RDA's problem can thus be reformulated as "how to understand and manage a complex adaptive system". We have developed a method and a practical set of tools to support an RDAs decision making process : (1) A participative system decomposition method, wherein a joint language is created for the multiple disciplines required to understand the problem. The process leads to a joint problem formulation and to a formal language, an ontology, which strictly specifies the concepts involved and their structural interrelationships. (2) An generic, modular and reusable Agent Based Model conforming to the Ontology. Inclusion of appropriate data allows for simulation of industrial network evolution and assessment of clusters economic and technological properties. (3) Knowledge feedback. By using different network growth scenario analysis becomes possible. The insights generated are used to support strategic decision making by the RDAs. We have developed a number of novel network metrics, that facilitate the understanding of industrial network evolution and facilitate decision making by the RDA. Initial findings will be illustrated by case study results developed together with Groningen seaports (NL)

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Clsing the Cycle of Aseptic Packaging: The Case of Entrepreneurial Networks in Brazil (Theme E 28)

From the outset, closing the cycle of materials has been one of the main normative objectives of industrial ecology. Regulation imposing firms to take back their products in the post-consumption stages is certainly a solution. But while policy instruments are a powerful in certain contexts, they are much less efficient in societies with limitations to enforcing them. This is why the increase in recycling rates of aseptic packaging in Brazil from 12% to 25% in the period 2000-2005 is a milestone: it was obtained without any regulatory push. The Brazilian branch of Tetra Pak, a Swedish company, made possible to recycle all components of the multi-layered packaging (paper fibber, aluminium and low density polyethylene), using a combination of economic, social and environmental incentives. As a result, total recycling was possible with benefits in all dimensions. This article describes the 'Tetra Pak case' and draws conclusions about market-driven solutions to post-consumption waste in other industries.

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Ecological Footprint Applied to the Input-Output Model **(Theme C 20)**

This work applies the ecological footprint method to the Brazilian economic input-output (IO) model. The footprint method calculates the amount of land required to support economic activities and absorb the wastes they generate. In the case of IO models, the footprints are allocated to sectors corresponding to distinct activities within the economy. The Brazilian IO table is available from the Instituto Brasileiro de Geografia e Estati;stica (IBGE). The footprint assessment, which is used as a basis for this study, is available from the Global Footprint Network (GFN). The IO-footprint model is produced in a spreadsheet, which allows the user to trace back the assumptions and data sources used to build the model. The analysis determines the ecological footprint intensity of 42 Brazilian economic sectors and can be used to develop more sustainable manufacturing processes. The assessment's results show which sectors have the greatest footprint based on per R$ 1 million and their total annual output. The dairy products industry has the highest footprint per R$ 1 million of final demand, whereas the steel mill sector has the highest footprint when the total annual industrial output of each sector is considered. The model construct may be used to identify the sectors that contribute the most to the final footprint of each industry. This information is a starting point for companies concerned with sustainable manufacturing and interested in the life cycle assessment of their products and services.

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Supply Chain Management in Local Networks of Food and Bioenergy – Small Scale Rural Entrepreneurs Pioneering Sustainable Development in Supply Chains **(Theme E 30)**

Efficient supply chain management requires co-operation between suppliers and customers in the whole production-consumption network. In the sustainability context, supply chains must also meet various economic, social and environmental requirements. The purpose of this paper is to define the specific aspects of sustainability in the local supply chains of food and bioenergy from the small scale rural entrepreneurs' point of view. In the local supply chain, small scale rural entrepreneurs have a role as a supplier for their clients and as a purchaser of production inputs. Vertically, the downstream supply chain covers refiners, retailers, wholesalers, public purchasing authorities, restaurants, final consumers and energy facilities. The upstream supply chain, in turn, covers the production inputs suppliers. Horizontally, supply chain management includes the co-operation between farmers. In the supply chain, sustainability aspects can be initiated by the stakeholder pressure, regulation or voluntarily by the entrepreneurs themselves. Market-oriented and personality-driven innovations associated with the sustainable supply chains can be seen as sustainable entrepreneurship. The methodology of this paper includes two case studies with interviews and a survey among farmers in Central Finland and secondary data analysis of various reports concerning economic, environmental and social impacts of the local food and bioenergy production. Specific sustainability aspects received from the case studies are categorized as downstream, upstream and horizontal supply chain aspects and as externally and internally driven aspects. As a conclusion, managerial on-farm implications are discussed. It is argued in the paper, that the analysis of sustainable local supply chains and sustainable entrepreneurship can be seen as a novel approach entailing an important contribution to industrial ecology as it reveals some essential dynamics of the bottom up processes in regions and in localities/communities.

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Planning for Sustainable Future Cities: Optimizing Density, Transportation, Land use and the Natural Support Systems. **(Theme B 15)**

Traditional urban land use and transportation planning process is inadequate for planning our future cities where sustainability would be the key. This requires intervention of multi-disciplinary approaches. In this paper, we have attempted to formulate a framework for an integrated model for planning sustainable urban areas. With the world getting increasingly urbanized, the distinction between cities and rural areas becomes increasingly ambiguous. This has deep implications considering the surrounding natural support systems for the city such as agriculture, forestry etc. which have been included as part of the urban land use in our model. The basic concept is to reconcile the trade-offs among various favorable parameters for cities, i.e. objectives, by using multi-objective optimization. This is done by dividing the city into various categories of neighborhood and optimizing each neighborhood individually in terms of population, building floor area and density, building area ratio and floor area ratio of the different building categories. At first, a series of objective functions are defined, such as, to achieve better quality of life through decreasing built-up area, increasing walking, bicycle and transit trips, along with reducing travel cost, air pollution and greenhouse gas emission. Then, the relationships among these parameters are developed statistically using the dataset from Nagoya. For example, building floor area density, transit accessibility, travel time, travel cost has been used to explain the various categories of trip production and modal choice. Then, an optimized transit network is simulated to connect these neighborhoods to achieve further reduction in travel time and cost at the city scale. The present modeling approach can be a useful tool to optimize various infrastructure, environment and socio-economic parameters in cities, thus providing a more sustainable answer to the urban planning.

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A New Concept and a Tool for Promoting Distributed Energy Systems at the Urban Scale
(Theme B 17)

Modern societies are presently facing major challenges regarding its energy system, such as the provision of long-term energy security of supply, and provision of an environmentally-sound system. It is fully acknowledged by governmental bodies worldwide that dealing with such challenges must necessary pass through the development of alternative distributed energy systems that address demand locally and incorporate increased shares of renewable energies. On the demand side, buildings, already responsible for 40% of total final energy consumption in Europe, are one of the main energy policy targets, both in terms of energy efficiency and of local micro-generation energy production means. In this context, a new concept and a tool, aimed at promoting distributed energy systems at the urban scale, is here discussed. This tool is designed so to aid the policy making process, by incorporating a framework for evaluation of policy effectiveness, while assessing the added-values of the microgeration systems from the viewpoint of those exploiting it. The innovation behind this tool lays on the design of micro-energy systems to accommodate all energy demand fluxes in the built environment (electricity, heating and cooling), based on system economic performance optimization, while putting into competition all available technologies. The systems design is conducted using a multi-variable economic-optimization algorithm, adopting a multi-level optimization concept. Technologies are here represented by thermo-economic performance maps, while competition rules for the system design, embracing environmental impacts, applicable regulation, availability of local energy resources, and networks interactions, are represented as system design constrains. Within a modular architecture, this concept has the advantage of allowing the economic viability analysis of various alternative strategies, within different scenarios. Aiming at supporting decision-making process of distributed energy systems at the urban scale, such tool will help promoting the design of regional distributed energy networks within the context of energy market liberalisation.

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Sustainable Energy Systems for Buildings: Assessing Water Heating Technologies **(Theme B 17)**

The European Directive 2002/91/EC of the 16th of December 2002, relative to the energy performance of buildings, set the need for a revision of the existing Portuguese energy building regulations and the establishment of a Building Energy Certificate System (essentially a labelling system). The recently revised building regulation diploma – RCCTE, which essentially regulates the energy performance of residential buildings and small service buildings without active ambient conditioning systems, set the minimum energy performance standards in terms of the building envelope using specific and overall energy performance indicators. Additionally, a novelty introduced by this revised diploma is the obligation to install solar thermal panels to provide for domestic hot water in residential buildings. A measure that constitutes an enforcement of the Programme Solar Hot Water for Portugal, which sets up a goal of 1000000 m2 of solar thermal panels to be installed until 2010 in residential and service buildings and in industrial applications. In the context of sustainable energy systems for buildings, the present work focus on the performance assessment of three technologies options for domestic hot water production: heat pump, solar thermal panels, and solar heat pump. Based on typical demand profiles, environmental and termoeconomic performances of the considered solutions are evaluated in a life cycle perspective and compared to each other using a reference system. On a first step, based on system design optimization for the thermal storage, and determining optimal operation strategy for the heat pump and solar heat pump technologies within a differentiated electricity tariff mechanism, solutions performances are evaluated in terms of capital investment, maintenance and usage costs, energy savings and systems efficiency, and equivalent CO2 emissions. While on a second step, the same analysis is performed considering future technology developments.

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The Role of Narratives in Problem Structuring Methods for Sustainable Urban Water Systems
(Theme D 27)

In our previous work, we explored the development of a novel problem structuring method (PSM) for decisions relating to the sustainability of large-scale infrastructure. It engaged with the inherent complexity of societal problems through a metaphysical framework grounded in critical realism; a sound psychological basis for “naturalistic decision making’ to bring a range of perspectives to consideration of the problem, such as those relating to social interaction, disparity of power, biases and heuristics; and rigorous consideration of the dynamic, emergent and uncertain properties of socio-eco-systems, and the inherent limitations of human cognition in dealing with these matters. Here, we highlight the value of problem narratives to facilitate stakeholder interaction. Such narratives are created using scenario analysis tools to map the range of responses of the system model to hypothetical disturbances. This narrative approach is aimed at identifying issues and their interrelationships through a widely accessible structuring of problem information, exploring differences between “as-is”, “likely” and “desirable” system states. In this way, issues are identified which require further analysis using tools such as economic modeling, multi-criteria analysis, preference elicitation etc. The advantage of this approach is that problem information can be explored both with an awareness of underlying philosophical positions and recognition of the cognitive limitations people face in dealing with such complex situations. This approach is demonstrated for the case study of a large metropolitan centre’s water supply infrastructure, and we offer some observations on the more general application of this approach to the promotion of Industrial Ecology.

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Uncertainty as Decision Support in Life-Cycle Interpretation (Theme A 5)

Estimating uncertainty for input parameters and result are an intrinsic part of performing quantitative assessments. In recent times we have seen the growing appreciation for uncertainty as part of life-cycle assessment (LCA), both in inventory sources and in impact assessment methods. While Monte Carlo analysis has become the most widely used tool for inclusion of uncertainty in calculations, we lack methods to interpret uncertainty in LCA results, and guidelines for operational use of uncertainty is missing. This presentation is an effort to use uncertainty as part of the input from LCA to the decision making process. We present results of a case study comparing various offshore drilling technology options. The study compares two different drilling fluid systems, two different mineral bases added for density control, two different waste treatment options and two different locations. In all this gives sixteen product systems offering the same functionality. Results are interpreted using uncertainty intervals offered by Monte Carlo analysis, including uncertainty in inventory and impact assessment data. The purpose of the study is to investigate whether or not we are able to recommend one of the technology options over the other given a short-list of high-priority impact categories. For offshore technologies, human health and the marine environment are the most important decision attributes.

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Aristotle Natural Law as a Rule to Elaborate a Set of Indicators within Industrial Ecology's Framework **(Theme D 26)**

This research addresses some of the underlying philosophical and ethical issues of industrial ecology. In particular: what kind of ethical rule is it necessary to respect for developing a set of indicators able to help implementing sustainable development, including the strong version of sustainability? The related questions will be: 1. Why a set of indicators is better than a synthetic one like Ecological Footprint? 2. What kind of ethical and technical conditions are necessary to build a meaningful set of indicators on the use of forests, fisheries, fresh water, and on greenhouse effect gases emission, heavy metal release, chemical products release, and soil degradation? 3. Is it obligatory to justify this set thanks to utilitarianism or distributive justice, or is it possible to draw another ethical path rooted in natural law and corrective justice? This paper is built on the assumption that mankind must preserve the Biosphere's role for services like climate, and symmetrically must prevent the complete substitution of nature by artifacts. The natural law of Aristotle will guide the presentation of the ethical requirements to elaborate a coherent set of environmental indicators. The easiness of Aristotle's principles of justice will be put in perspective with two concrete examples of indicators representative of the main problems faced in building such a set. The suitability of this set for utilitarianism, distributive justice and corrective justice will be discussed as well as the problem of coherence between indicators within the set structure.

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Enhancing Material Efficiency in a Dynamic Material Flow Model - The Case of Forest-Based Industry **(Theme A 9)**

Generally, technical progress is seen as an important measure to reduce material and energy utilization by companies, and thus, to reduce the environmental impact of production processes. This view focuses in most cases only on the industry under consideration. Effects, either positive or negative, on other sectors and on material and energy utilization of an entire national economy are often ignored. Furthermore, the discussion of the effects grounds often on static models. The objective of the presentation is twofold: The presentation will at first discuss the impact of enhanced material efficiency as a kind of technical progress on the structure of material and energy flows of an economy using a dynamic material flow model. The discussion will concentrate on selected manufacturing processes of the forest-based industry. The forest-based industry is seen by some as one of few major industries that can actually become sustainable. Because the nucleus of the industry is a versatile renewable material, it has the potential to close the carbon cycle; furthermore, forest-based products are recoverable and recyclable. Secondly, to analyse the importance of dynamic relations between sectors and processes, the results of the first step will be compared to a static model. The discussion grounds on a dynamic material flow model of Germany, called CarboMoG (Carbon Flow Model of Germany). CarboMoG allows to identify carbon flows, sources and sinks in German anthroposphere. It models the concurrent energy and non-energy use of fossil and non-fossil carbon sources. The advantage of the chosen approach is the possibility to analyse potential impacts of technical progress on material and energy flows considering the interdependencies between sectors.

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The Requirement for Quantitative Verification of Waste and Resource Management Policy (Theme A 2)

Waste management policies in Europe promote various strategies to enhance resource conservation. Among these strategies are (1) reuse of products in order to extend their life-time and (2) as high as possible rates for recycling of materials. Two case studies are presented which show that these strategies are not necessarily the most efficient means to achieve resource conservation and environmental protection. The first case study investigates the effect of reuse of electric and electronic household appliances. The contribution to resource conservation is determined by materials and energy balances. Two extreme scenarios are compared: one scenario with no reuse of products (normal life-time) and another scenario where all selected products are reused resulting in life-time extensions between 50 to 100%. The result is that even intensive product reuse of electric and electronic equipment reduces total resource consumption (materials and energy) of a developed economy by less than 1%. It is shown that efficient recycling is more relevant for sustainable materials management than reuse. The second case study compares two technologies for recycling of cooling units. One technology is designed to achieve the maximum rate of materials recycling whilst the other technology is a mix of materials recycling and energy recovery. Emissions, energy consumption vs. gain and resource conservation of both technologies are compared. The result is that maximum recycling rates based on technological feasibility do not necessarily result in goal-oriented waste management. Hence, more sustainability in waste management cannot be achieved by solely stipulating and increasing recycling rates. One common conclusion of both studies is that it is a requirement in decision making to carry out quantitative studies in order to avoid any influence of ideology resulting in suboptimal decisions.

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The Contemporary Global Nickel Cycle: Results, Analysis, and Outlook (Theme A 1)

A cross-sectional analysis of nickel is presented for the year 2000. The analysis covers the entire technological nickel cycle and extends to the 60 countries most relevant to nickel worldwide, including both developed and developing countries. Nickel is a widely-utilized industrial metal which is chosen for its corrosion- and heat resistance and its good plating properties. It is commonly used in alloys, with stainless steels covering about 65 percent of the total usage. The characterization of the nickel cycle includes its extraction, fabrication & manufacturing, utilization, end-of-life, waste management & recycling, and the respective trade flows at all stages. The analysis examines how countries use nickel along the stages of its cycle, both in aggregated form and per capita. This provides the basis for a better understanding of where resource-intensive processes like production and fabrication take place, and of where end-use by consumers dominates a country's cycle. Insight into the use of nickel in economies of different developmental stages will be given through an analysis of its material intensity of use. The results of this contemporary study also provide a basis for the analysis of historic and future nickel waste flows: By having identified and characterized almost one hundred commodities at the level of intermediate and manufactured goods, it is possible to quantify the nickel waste flows by combining historic trade data with the lifetimes of key nickel end-use products. Finally, it was possible to verify the reported data on the international trade of commodities through a mass balance between data on indirect trade of nickel and data on nickel related scrap flows. As a result, insight on the general qualitiy of the data relative to the trade of commodities can be derived, as is demonstrated by the example of Mexico.

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Material Flow Accounting and Waste Production Forecasting - A Tool for Decision Making (Theme A 2)

The physical nature of the economy is emerging as a new paradigm, based on increasing public recognition about environment-economy interconnections. In this context, modern economies can be seen as organisms that metabolize natural resources to fulfil their functions (Matthews et al., 2000). The material resources that are used by the economy will, ultimately, generate wastes or pollution which will be discarded back to nature originating high environmental burdens. In this context, waste and pollution can be regarded as inefficiencies of economic systems, and as a consequence sustainability policies, at an EU level, have been considered resource use and waste production as priority. A material flow analysis based model is used to forecast waste production trends of different resource categories taking into account resource use scenarios. The model considers the dynamic relation between resource consumption and waste generation, taking into account the economic output, products life cycle times and the way materials are discarded back to nature. It constitutes as a tool for end-of-life management and technology decision making. Using Portugal as case study, four aggregated material categories were selected, namely biomass, fossil fuels, non-metallic and metallic minerals. Three scenarios of resource consumption were considered. First a baseline scenario that projects further trends of material consumption. A second considering a stabilization of resources consumption and a third considering a reduction in resource use. It is shown that for certain material and products, future waste patterns are mostly driven by past production and consumption patterns, and for others, they are almost dependent on the way society will consume resources in the future. Results are used to discuss the dynamic and complex interaction between the use of resources, waste production and recovery of materials, in order to contribute for the definition of more integrated policies for resource use and waste management.

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Moderating the Impact of Sustained Energy Interruptions through the Design and Construction of Low-Energy Homes (Theme B 19)

Sustained energy interruptions during the heating season can lead to catastrophic property losses and injury. As the 1998 ice storm in Eastern Canada revealed, modern homes are dependent on a continuous supply of energy and are, therefore, vulnerable to sustained power interruptions. If the energy supplied to homes is interrupted for more than 24 hours, both the occupants and building components can be exposed to damaging conditions. This paper will show that low-energy homes perform better by moderating the impact of prolonged energy interruptions. For the cities of Toronto, Edmonton, and Vancouver, homes have been modeled based on the provincial building code, the Model National Energy Code (MNEC) and a more sustainable, “advanced design”. For each scenario, “cooling curves” were generated to determine the time required for the interior temperature to drop below two critical temperatures – one based on occupant thermal comfort and another based on freezing of the plumbing system. This paper also estimates the amount of supplemental energy required to maintain the model homes above the critical temperatures when energy supply is interrupted for a long period of time. This study shows that better built, more sustainable low-energy homes are far less vulnerable to sustained energy interruptions.

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The Centre for Interactive Research on Sustainability (Theme D 24)

The Centre for Interactive Research on Sustainability (CIRS) is dedicated to research, collaboration and outreach that leads us to workable solutions for the challenges of urban sustainability. As a building, it will be a living laboratory that pushes the frontiers of sustainable construction materials and building techniques. Located on the Great Northern Way Campus, the building will be close to downtown Vancouver and on major transit routes. As a research program, it will create new knowledge and new solutions faster by collaborating between disciplines, among academic institutions and among public, private and non-profit sectors. As a member of many communities, it will reach out and engage with other communities in long-term planning for a sustainable future. CIRS exists to accelerate sustainability -- to find solutions to the challenges of urban development faster and more effectively than ever before.

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Fair Trial for Industrial By-Products - Importance of System Boundaries (Theme A 3)

The use of industrial by-products in the Swedish society has a potential that only to some extent is explored. There are drivers, for example, in the possibility to economically gain from reuse by selling the material and avoid taxes. Still the movements in this area are under its potential. One reason to this could be the precautionary principle that hinders the development because of possible environmental impacts through leakage of toxic substances into the nearby environment. However, the underlying reasons to reuse is often efficient use of resources. Mainstream environmental assessment of reuse in Sweden that is performed in the process of development consent and also in research, mainly addresses the narrow scope of the material, leaving out an assessment of resources use. All in all, there is a lack of studies addressing environmental aspects of the motives to reuse that could diversify the picture of reuse of industrial by-products. While assessing reuse of industrial by-products and construction materials a framework addressing scope and system boundaries was developed. As system boundaries to a large extent decide which issues could be addressed and what actually could be studied the environmental assessment methods were organised in four system levels: the material level, the local environment level, the narrow life-cycle level and the industrial system level. When selecting system boundaries, methods and indicators, researchers indirectly decide on which environmental pressures we consider the most important. In order to apply a holistic approach to environmental assessments of reuse of construction materials, the system boundaries needed to be widened from the material level to the broader scope in a higher level. This presentation will give an orientation of the structure of the assessment framework and its possibilities to contribute to a diversified debate concerning the outcome of environmental assessments of reuse.

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Environmental Performance of Reuse of Concrete and Clay Bricks (Theme F 34)

Reuse is a measure for resource-saving materials and energy use, which is stressed by the Swedish government, e.g. through the national strategy for non-toxic and resource-efficient material cycles (Swedish Government, 2004/05:150). Reuse is here used as a general term for any kind of reuse and divided into recirculation, upgrading and cascading, according to the degradation of the inner material structure. Reuse of construction materials in society is mainly done with the belief that any kind of reuse is environmentally beneficial. However, this assumption is seldom critically assessed. The aim of this project was to examine under which conditions reuse of construction materials in the Swedish building and transportation sectors is beneficial to the environment. In order to identify critical conditions, the environmental performance of actual building projects that to a large extent utilised reused building materials was assessed. Methods and tools employed in this work were required to be able to simultaneously address different system boundaries and also involve simplification. After calculating energy use in a life-cycle perspective for the recirculation, upgrading and cascading of larger building reuse projects of concrete and clay bricks, it is not self-evident that reuse is beneficial for the environment. It mainly depends on the use of auxiliary materials and their embodied energy, but also the primary energy use for the reuse processes, such as transportation distance and mode between the deconstruction and construction sites. In order to improve the environmental benefits of reuse, primarily the auxiliary materials used in current reuse projects should be minimised. Otherwise, there is a risk that the energy use for these materials turns reuse into an unfavourable process for the environment. Furthermore, reuse should preferably be environmentally assessed with a wide scope before implementation.

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Incorporating MFA into Spatio-Temporal Simulation of Material Consumption and Embodied Energy: Example of Construction Material **(Theme A 6)**

Material Flow Accounting (MFA) is a widely accepted technique for quantifying the extraction of resources, their transformation through production, consumption and transport, and their eventual release into the environment. In accounting for the overall material flows, MFA provides a better understanding of the metabolism of socio-economic systems. However, existing MFA methodologies lack any consideration of the spatial interaction within socio-economic systems, and as a consequence, hinder its use in spatial planning and environmental governance. Progresses in spatial analysis (e.g. Decision/Planning Support Systems, DSS/PSS) have indicated the potential of integrating spatial attributes with MFA in a format that can be used by a wide range of stakeholders. We explore such a framework in the simulation of material consumption and embodied energy in the Built Environment, which is being piloted in a project funded by the Republic of Ireland's Environmental Protection Agency (EPA). This places the principles of MFA (e.g. EUROSTAT 2001) within a spatial and temporal framework. It builds on the EPA-funded project titled Resource Flow Analysis and Ecological Footprint of Ireland - 'Island Limits', but focuses on the local scale. The aim is to develop a GIS-based system that enables spatial allocation of the construction material flows and embed that in the simulation of embodied energy in the built environment. The system combines economy-wide MFA and the environmentally extended Input-Output analysis of Island Limits, with spatio-temporal land use data at Ireland's Local Authority level. Alternative scenarios of embodied energy are generated through simulating the material consumption and energy use within the physical structures, with a view to linking this with models of building operational performance. This also creates possibility to assess the energy implications of the spatial interaction between some activities, e.g. home to work travel.

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Industrial Clustering: Is it a Panacea to Industry's Environmental and Economic Challenges in Zimbabwe? **(Theme C 20)**

Developing competitive industries with a world-class operation structure is imperative to sustainable and resilient growth of the manufacturing sector within the region. The industrial clustering concept that has gained worldwide recognition as the impetus for the promotion of sustainable development leveraged with economic viability is currently being adopted in Zimbabwe and other developing countries. This research is therefore aimed at providing an overview of the potential contribution of industrial clustering to green manufacturing in Zimbabwe and thus providing the basis on which the clustering concept can be promoted. A statistical package was used to determine environmental performance improvement achieved as a result of industrial clustering in the key issues of water, wastewater, solid waste management, energy conservation and air pollution. The data obtained is of particular relevance to stakeholders in the environment, industry and government. It helps to develop commitment among industries towards clustering and cleaner production. The lessons drawn can be applied to other countries, particularly developing ones.

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Producer Responsibility Organizations Assuming Producer Responsibility for End-Of-Life Products in Portugal **(Theme A 13)**

The “EPR-extended producer responsibility” policy strategy, which is prevailing at the EU for several products types, has driven the environmental concerns to the product life cycle level, and this has contributed to promote design for environment practices, precluding the shift of environmental burdens from process to processes or to different life cycle phases (Ferrao, 2002). The application of the EPR concept during the last years resulted implied that the producer’s responsibility has been extended to the post-consumer phase in the product life-cycle, and this was one of the pillars of the Portuguese waste policy, together with the improvement of MSW recovery and hazardous industrial waste treatment. The methodology adopted by the Portuguese government and producers for several waste streams is analysed in this complex framework, in an integrated way, focusing on those that have been subjected to EPR policies, namely general waste, medical and pesticide packaging, used tyres, used lube oils, end-of-life vehicles (ELV), waste electrical and electronic equipment (WEEE) and portable and car batteries. The policies effectiveness and results are analysed taking into account key policy, environmental and economical factors and instruments that contribute to the EPR implementation process. The implementation of EPR, in general, resulted in an increase in the performance of waste management activities in Portugal. Waste management became more organized, closely monitored and better understood by the different stakeholders involved. EPR policies also contributed to an increase in the quantity and quality of waste recovered and recycled. Preliminary results showed that the implementation of EPR policies in Portugal, in early stages, for some waste streams, contributed decisively to reduce the overall environmental impact associated with the waste sector and induced new business opportunities at various levels.

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Australian Material Resource Flows and the Global Economy: an Application of the Australian Stocks and Flows Framework to Analyse Australia's Resource Futures **(Theme A 7)**

When compared to other OECD countries, the Australian economy shows very different characteristics of natural resource use. While many OECD countries have stabilized their resource use, Australia, despite its high standard of living, has remained a materially intensive economy because of a continued expansion of primary extraction to support a growing urban population but also for primary exports of mainly metal ores and fossil fuels and also products from agriculture reflecting Australia's role in the global economy. As a consequence, unlike other industrial economies, the Australian material and energy demand shows no saturation during recent decades and although per capita levels of material and energy use are already comparably high, the throughput of materials and energy will grow in the future resulting in a number of local and global environmental impacts such as rising levels of CO_2 emissions, land use change and toxic releases from mining and agriculture. With the aid of the Australian Stocks and Flows Framework (ASFF), a highly disaggregated simulation framework, we analyse developments in resource use in the Australian economy since the 1970s and discuss scenarios of future resource requirements. The framework operates at the scale of the whole economy and allows for simulations of future flows based on a historical data set and a simulation model. In this model, we account for physical processes of demography, production, consumption, infrastructure, natural resource use and international trade. The main objective is to analyse the interplay and trade-offs among issues including population, affluence, economic structure and technological innovation. In this presentation we discuss the future challenges for sustainable resource use in the light of the impacts within Australia as well as of Australia's role as a major supplier of raw materials to an increasingly integrated global economy.

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Mass Flow Assessment and Assessment of Recycling Strategies for Cathode Ray Tubes in South Africa (Theme C 23)

Awareness is growing regarding risks associated with waste electrical and electronic equipment (e-waste) in developing countries. As emerging economies such as South Africa are producing more and more of their own e-waste, sustainable recycling systems are not in place. Cathode ray tubes (CRTs) are a major problem for further recycling in South Africa. This study provides background knowledge for a sustainable management of end-of-life CRT screens considering both local and overseas recycling scenarios for the Cape Metropolitan Area in South Africa. A mass flow assessment of CRT computer monitors and TVs showed a significant consumer stock growth, while only little CRT devices are disposed of at landfill sites. It is expected that in the year 2007 some 400 tons of CRT monitors and 600 tons of CRT TVs will become obsolete. Local brick manufactures and the building industry is able to use the CRT glass in their processes. Neither the assessed local metal smelters nor glass manufacturers were prepared to use CRT glass in their processes. From the best available technologies applied in many western countries, the use of CRT glass in the production of new CRTs and the use of CRT glass in the copper/lead smelting process were included as recycling scenarios. In total eight combined local / overseas scenarios were assessed towards their sustainability using the Multi Attribute Utility Theory (MAUT) methodology. A set of attributes was defined to evaluate the scenarios including economical, environmental and social attributes. The study shows that the manufacturing of new CRTs from recycled CRT glass is the most sustainable option with high potential of job creation in South Africa and the highest environmental benefits. This option includes the pre-processing of CRT screens locally and the shipping of glass cullets to a CRT manufacturer in Europe.

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Comparative Life Cycle Assessment of Ordinary Portland Cement Concrete and Geopolymer from Coal Fly Ash (Theme B 19)

Ordinary portland cement is produced in a high-temperature kiln that evolves carbon dioxide from limestone to produce calcium oxide – the primary binding agent that hardens when hydrated. About half the carbon dioxide burden due to production of cement is from the consumption of fossil fuels and about half evolved from the raw materials. Consequently, cement manufacture is a major contributor to global carbon dioxide emissions inventories. However, substitution of class C coal fly ash (which is rich in calcium oxides) for ordinary portland cement can in many instances reduce the expense and life cycle environmental impact of concrete infrastructure without sacrificing engineering performance. Where coal-burning utilities have been successful marketing class C coal fly ash to the construction industry, a mutualistic interaction has evolved that reduces waste disposal costs in the utility industry and raw materials costs in construction industry. Nonetheless, many utilities use a type of coal that produces class F fly ash, which is not suitable for use in cement, rather than class C. This research presents some of the potential life-cycle environmental advantages of using class F fly ash to produce a different type of binder called geopolymer. Unlike ordinary Portland cement, geopolymers rely upon alumino-silicate bonds instead of calcium. The resulting material is more like ordinary rocks. Although it obtains high early strength, weathers well, and has a much lower life cycle carbon dioxide burden, this research investigates the end-of-life environmental leaching properties to determine whether geopolymers made from class F ash may present a source of heavy metals in the environment if used extensively in civil engineering infrastructure.

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Trends and Determinants of Household Water and Electricity Consumption in Shanghai, China
(Theme A 14)

According to the United Nations, China's urban population may grow from 456 million in 2000 to 875 million in 2030. With rapidly growing urban population, rising standards of living, and decreasing family size, household water and electricity consumption will continue to soar over the next few decades. For instance, the annual growth rate of per capita residential electricity consumption in Shanghai exceeds 6 percent between 2000 and 2004. Associated environmental impacts such as water scarcity and pollution, acid raid, and greenhouse gas emissions will also continue to mount. Lack of empirical research about China's household water and electricity consumption has increased the difficulty of making informed policy choices for mitigating the negative impacts of these trends. The research aims to elucidate the patterns of household water and electricity consumption and to explore the driving forces underlying the patterns. A questionnaire was developed to survey household annual water and electricity consumption, as well as household size and composition, total income, education level, employment status, and tariffs of water, electricity, and waste management. The research randomly selects 70 households each (altogether 210 households) from three types of residential communities in Shanghai, i.e. high-rise housing (8 stories and above), multi-story housing (4-6 stories), and traditional courtyard/two or three-story buildings for in-house interviews. It is found that per capita water use in Shanghai grows relatively slow while per capita electricity consumption keeps in rapid rise. Although the advance of building and consumption technology leads to declining water and electricity use per unit of floor space, the remarkable growth in per capita housing space offsets the technology efficiency gain (i.e. rebound effects). Multivariate statistical analysis on empirical data is conducted to explore the patterns of household water and electricity consumption.

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Organizational Forms and Determinants of Industrial Symbiosis in China: A Transaction Cost Economics Perspective (Theme C 22)

Industrial symbiosis (IS) is based on the concepts of inter-firm material and energy exchanges and shared resource management. By means of symbiotic inter-firm links, businesses strive for a collective benefit greater than the sum of individual benefits that could be achieved by acting alone (Lowe, Moran and Holmes 1995). IS has been hailed as a practical approach towards accomplishing economic growth and environmental protection simultaneously (Chertow and Lombardi 2005, Jacobson 2006). Nevertheless, the widespread efforts to promote new IS have resulted in relatively little success (Chertow 2006). Gibbs et al (2005) concluded that "initiatives based upon the interchange of wastes and cascading of energy are few in number and difficult to organize." To realize IS, the companies involved have to consume resources to overcome a range of barriers, such as informational, regulatory/legal, organizational/motivational barriers. Many of the resources can be characterized as transaction costs associated with operationalizing IS relationships. For IS to occur, it is necessary that net private benefits must be positive, or total private benefits must exceed total private costs, i.e. the sum of production costs and transaction costs for any firm involved in the IS relationship. While the total private benefits and production costs tend to be stable at a given time frame and technological level, transaction costs economizing becomes a determining factor as to whether the net private benefits of IS would be positive or not. IS can take a variety of organizational forms, ranging from spot market transaction, to relational contracting, to joint ownership, and to intra-firm organization. Transaction cost economics aims to explain how IS partners choose, from the alternative organizational forms, the arrangement that offers protection for their relationship-specific investments at the lowest total costs, i.e. economizing transaction costs.

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Empirical Research On Corporate Environmental Governance -A Case Study In Qingdao, P.R.China **(Theme C 22)**

In the past decade, there are strong trends in China that favor economic development while ignoring environmental degradation. Rapid economic growth has help China to become one of the most important world economic powers. However, the rapid growth has not come without a price. Fortunately, the narrow approach of maximizing GDP growth without considering other costs, including environmental, is being gradually replaced by more balanced policies at the central and local government. However, at the bottom level, there is still a long way to educate local government officials, owners, employees and the public to re-formulate their views on the development. More importantly, there is a lack of understanding about the corporate environmental governance, which is the real power that plays important role in local environmental protection. The authors conducted a survey in 2006. This survey was completed for more than 100 enterprises in Qingdao, which are a key textile, light industry and chemical production center in China. The city has special advantages in household electrical appliances, electronics, locomotive and rolling stock manufacture as well as food processing. With adopting Analytic Hierarchy process and Delphi Technique to ascertain the weight of indicators, the authors establish a model which includes three subsystems: corporate environmental construction, production process environmental control and enterprise environmental consciousness to evaluate the corporate environmental governance in Qingdao city. By this research, it is systematically analysis the effect on corporate environmental governance by the features of size of enterprise, ownership, product markets and industrial category; statistically analyze the determining factors in corporate environmental governance in different types of corporations. The paper will also explore the potential solutions that will help improve corporate environmental governance to achieve sustainable development in China.

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A Dynamic Planning Framework for the Developing Eco-Industrial Parks (Theme F 35)

Industrial parks are alike organic lives, some enterprises creating, some dispersing. In fact, a well-operating eco-industrial park (EIP) must have a good balance between land use, infrastructure construction and industrial development. Since the first batch of Economic and Technological Develop Areas (ETDA) were established in 1984, there are more than 3,000 industrial parks in China, including national, provincial and township levels. Most of them are under-developed and evolve rapidly. With the promotion of EIP initiatives, how to plan and build industrial parks into EIPs gets more and more attentions. This paper presents a dynamic planning framework for these developing industrial parks from technological perspective, including the following five main steps. 1. Targeting. What are the targets for energy and/or resources usages, or what are goals for waste minimization of EIPs? Pinch analysis technique, a thermodynamics-based tool for analyzing production processes, may contribute to this question. 2. Topological structure. What topological structures are required to achieve these targets? Centralization or distribution, this question exists in almost every infrastructure planning problems. 3. Multiobjectivity and uncertainty. There exist several goals to be traded-off, there also exist many uncertainties during the development process. 4. Ownership diversity. There exist many enterprises in EIPs. How to seek the balance among them? 5. Co-evolution. How to deal with the co-evolutionary problems existing between land usages, infrastructure construction and industrial development?

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Integrated Modelling and Decision Support for Post-Tsunami Nicobar Islands **(Theme D 27)**

The presentation reports on an ongoing research project (RECOVER) whereby scientific support is generated for the planning, implementation and evaluation of reconstruction and development options for the indigenous population of the Nicobar archipelago in the aftermath of the 2004 tsunami. The Asian tsunami has clearly revealed the vulnerability of coastal communities with respect to dealing with ecological hazards. An area that was highly affected by the tsunami were the Nicobar Islands, an archipelago belonging to India located in the Bay of Bengal. Consequently, a third of the indigenous population was wiped out and those that survived were rendered homeless and without an economy to support them. Relief and rehabilitation concerning these islands were not only severely constrained with lack of information on the inhabitants and the islands but were equally driven by the political economy of aid leading to social conflicts and threatened with unsustainable trends. By employing systems dynamic modelling together with intervention science, the research aims to guide interventions that are ecologically sound, culturally appropriate, socially equitable and economically feasible based on years of previous research and credibility in the region. The research illustrates the crucial role of sound scientific information in informing appropriate decisions in the wake of a disaster.

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Comparative Energy, Environmental and Economics Analysis of Traditional and E-Commerce DVD Rental Networks **(Theme A 4)**

This study is a comparative life cycle assessment of two competing DVD rental networks: e-commerce option, where the customer orders the movies online, and the traditional option, where the customer personally goes to the rental store to rent a movie. The analytical framework proposed is applied to considering a customer living in the city of Ann Arbor, Michigan (U.S). The primary energy and environmental performance (criteria air pollutants, greenhouse gas emissions) for both the rental networks are presented in the form of a multi-criteria LCA. In contrast to other studies presented, which found that impacts are highly sensitive to the transportation phase, differences in the performance of the two alternatives considered are due to the selection of the package used to deliver the DVDs. The package selected by the traditional business accounts for 67% of the difference in total energy consumption of the two alternatives. Results show that the e-commerce alternative consumed 33% less energy and emitted 40% less CO_2 than the traditional option. A set of sensitivity analyses performed, test the influence of distances traveled and transportation modes, DVD and DVD packaging reuse on the final results. The mode of transportation used by the customer in the traditional business model also affects global emissions and energy consumption. A maximum of 12% reduction in primary energy is possible in the traditional network when the customer decides to walk to the store; however, the e-commerce option performed comparatively better despite all transportation modes tested. A novel economic indicator (ESAL) is used to compare different transportation modes based on the level of stress exerted on the pavement. The two networks are also compared based on full cost accounting. Consistent with its energy and environmental advantages, the e-commerce network exerts $1.17 lesser economic impact than the traditional network for the functional unit tested.

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Modelling Industrial Symbiosis Using System Dynamics (Theme D 27)

In today's competitive world, Industrial Symbiosis (IS) is seen as a model for more environmentally responsible production. The issues and challenges towards building industrial symbiosis are varied in terms of concept and definition, design and planning strategy as well as industrial symbiosis modeling and optimization. One of developing area presented in this paper is the quantification of the IS benefits. The assessment of benefits in the literature is mainly descriptive, yet leaving out the specific methodology applied. Quantifying benefits of industrial symbiosis is not an easy task. The benefits in terms of economic, social and environmental aspects must be well-addressed to assess the overall picture of industrial symbiosis. This paper aims to propose system dynamics approach to modeling industrial symbiosis. The description and characteristics of system dynamics approach will be briefly introduced. The factors that must be taken into account when modeling IS will be presented. The discussion on how system dynamics could be used to model IS will then further explored. This approach will then be contrasted with other approaches that have already been used in the literatures so that the advantages and disadvantages of system dynamics approach can be examined. Last but not least, we explore the potential of future research applying this approach to real-cases and further building a generic framework for modeling industrial symbiosis.

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An End-of-Life Decision Methodology to Support Recycling Practices in the Footwear Industry
(Theme A 8)

The footwear industry is a diverse manufacturing sector using a variety of materials and producing a range of distinctly different products. The sector, over the last years, has placed significant effort in improving energy and material efficiency, but in comparison little effort has been directed at recovery and recycling of shoes at the end of their useful life. In reality, most of the worn and discarded shoes are being disposed off in landfills. Producer responsibility issues and forthcoming legislations as well as increasingly environmental consumer demands expected to challenge the way the global footwear industry is dealing with the its end-of-life products. Design and material selection activities in the footwear industry clearly influence the choice of the appropriate end-of-life treatment option. This paper presents an investigation into the steps required to consider the end-of-life implication of shoes and promote post-consumer recycling practices in the footwear industry. The paper highlights the potential benefits of developing an end-of-life decision methodology to support the adoption of the most appropriate reuse, recovery and recycling option for post-consumer shoes. Such methodology in addition to supporting design and material selection processes could also provide benchmark information for the best end-of-life practise for a selected range of shoe types. The paper concludes by providing a case study for shoe waste management to demonstrate the practicality of this decision methodology.

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Using GIS, Process Simulation and Systems Optimization to Maximize Industrial Water Reuse
(Theme B 16)

In a Canadian case study, a geographical information system (GIS) is combined with process simulation software to perform water and energy balances on publicly available and limited, privately attained company information. Results of the water and energy balances are used in conjunction with objective functions developed in collaboration with industry advisors to find optimal water reuse relationships focused on maximizing water reuse and minimizing the required energy input between companies. Optimization results are presented as process flow diagrams along with a GIS map representing the optimal water sharing network. This methodology seeks to act as a decision support tool to provide municipal engineers, city planners, and participating companies with quantitative and qualitative information regarding the feasibility of potential eco industrial relationships.

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Kyoto Targets for Growing Urban Regions: Using the Case Study of Geneva, Switzerland to Understand the Potential and Limits of Regional Approaches to Climate and Energy Policy Implementation **(Theme B 17)**

This work uses a detailed case study of the urban canton of Geneva, Switzerland to approach regionally-based climate and energy policy setting and implementation. The canton of Geneva has adopted Switzerland's Kyoto protocol commitment of a 10% reduction in 1990 level carbon dioxide emissions by 2010. Due to Geneva's population growth, this corresponds to an ambitious 25% per capita emission decrease. This research investigates the successes and failures of Geneva's energy action plan towards emission stabilisation and reduction. Key issues are identified and discussed, including the potential and limits of regional action, data requirements and enforcement burdens, multi-stakeholder engagement, the role of the energy production sector and renewable energy promotion at the urban and regional scales. On this basis, contrasts between regionally-based energy and climate policies in Switzerland and the USA are investigated. The hypothesis is presented that the diverging policy priorities between the USA and Switzerland reflect radically different assumptions regarding the links between energy consumption and economic development. However, further research that may either prove or disprove these assumptions is required.

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Material Flow Analysis (MFA) and Economic Evaluation of Material Flows as a Combined Model for Durable Consumer Goods (Theme C 20)

The presented MFA model depicts the material flow and its economic evaluation of durable goods through a process chain, covering consumption, recycling and disposal. The model combines a stock-driven consumption model with a recycling model, in which the material flows are controlled by economic factors. In the stock-driven consumption model, the stock development determines the life-span of the individual items in the stock, as well as the variations of flows into, and out of, the consumer stock. The consumption stock depicts a sequence of individual consecutive stocks. They represent a cascade use of consumer goods, from first users, second hand users and so on. Such a cascade use is characteristic for the way in which many durable goods are used in countries in economic transition. The consumption model determines how much material reaches the recycling model. In the recycling model, the final fate of the material flows is determined by its value for recycling industries. Whether certain consumer goods are recycled and whether they are treated in a particular process is determined by the market price recyclers are willing to pay for the material. The model introduces threshold values for individual recycling practices. These threshold values can be the price recyclers pay for scrap material or the charges which are levied for the recycling and disposal services.

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Utilizing Leontief 's Price Model to Estimate Input Structures (Theme A 4)

The combination of physical life cycle inventories with input-output data has gained interest within the LCA and eco-balance communities in the recent years. Several alternative approaches perform this combination has been developed. This paper presents an approach to combine input-output based data with physical life cycle data into a hybrid inventory utilizing Leontief's price model to tune and adapt data. The motivation for the proposed method is provided based on experiences form case studies. In many cases, and for various reasons, LCA practitioners may often experience less than perfect availability of information. So, rather that starting from scratch we here present an approach that begins with, and then adapt, data from an input-output data set. This implies starting with an average data set rather than starting with blank sheets. We further show how the input-output based data is combined with original key data and adapted to represent the processes in question. The application of Leontief's price model is essential in adapting the input-output data under imperfect information of process inputs. We present a formal approach to perform this adoption, demonstrate the method with a small numerical example and presents results from an application. Through this it is shown how the method allows for a relatively fast approach to establish hybrid LCA inventories under imperfect access to data using Leontief's price model.

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Mongstad, a New Kalundborg? **(Theme E 29)**

The Norwegian oil company Statoil own two refineries. One is situated at Kalundborg, in Denmark, while the other is situated at Mongstad on the Norwegian west coast. The comparison between these two are striking. While the Kalundborg refinery sits in the midst of the famous eco-industrial park and benefits from resource exchanges with the other facilities there, the situation at Mongstad is quite the opposite. However, as with its sister refinery in Denmark, the resource and energy flows through the Mongstad refinery are substantial. The excess hot cooling water, refinery gas and potential delivery of process steam at different levels of pressure provides motivation for investigations into activities that could be co-located with the refinery. The research challenge posed is basically that of designing an eco-industrial park almost from scratch. This involves addressing several methodological as well as empirical questions. In this presentation we present how we have addressed the challenges of assessing symbiotic potential of activities with respect to physical and environmental modelling as well as the economic aspects. The presentation will focus on case studies which look at processes co-located with the refinery that produces hydrogen and electricity.

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Chemical Systems Engineering Models for Eco-Industrial Parks (Theme F 35)

Our hypothesis is that the design and development of eco-industrial parks (EIPs) can benefit greatly from a more sophisticated modeling of energy and material flows. Today most models are black-box models: individual park members and processes are represented by empirical input/output models. Such black-box models cannot used to identify and explore a better matching of processes and can also not be used to detail the interface between the different members (process parts). There are also difficulties with matching energy and resource streams of differing quality. We are currently testing existing chemical engineering modeling tools and develop as part of this process new modeling tools that describe the processes in more detail. These models are on the top based on a physical description (white-box) and are, when necessary, augmented with functional relation between variables based on empirical studies or the regression of more detailed physical models (grey-box models). A challenge for this type of modeling is to address the appropriate level of model granularity and to combine descriptions at different levels of detail – depending on the purpose the model shall serve. We present two examples from our work with the Mongstad Pilot project. The first case addresses the refinery gas processing plant and analyses the quality and quantity of surplus energy available. The second case analyses the process integration of a new, potential hydrogen production facility into the Mongstad facility.

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Measuring the Performance of Eco-Industrial Parks' Operation (Theme E 29)

South Korean government has launched its long-term eco-industrial development plan in 2004. The plan lays out the strategic approach to achieve a "resources-circulation society" by 2019. As a part of the plan 6 existing industrial complexes are recognized for their transformation into eco-industrial parks. This study shows the method to measure the performance of eco-industrial parks' operation that is being applied to one of the 6 industrial complexes. The current presentation report the framework of the information network and the structure of the indicator system used for measuring the performance of the eco-industrial park's operation. Due to the dynamic nature of the current business environment, both inputs and outputs of an industrial system constantly change over time. Furthermore, a new facility may be introduced to an industry complex, or a facility may migrate to other location. Under such circumstances, it is not easy to determine how well the industrial park as a whole is performing. In this study, a framework to quantify the overall performance of an eco-industrial park is developed considering key environmental, economic and social aspects that are identified in consultation with the stakeholders. The data required to generate the performance indicator are voluntarily provided by the participating facilities through the Eco-Industrial Park Portal web site, maintained by the regional eco-industrial development center. Relevant personnel of the participating facility can logon to the portal and enter the basic information such as value added, key environmental emissions and job creation of the period. Such information is stored in the central database of the regional eco-industrial development center and analyzed using multi-attribute valuation method to measure the overall performance of the eco-industrial park. The indicator will be used mostly for internal purposes to keep track the development of eco-industrial parks' operation.

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Life Cycle Considerations for Environmental Management of an Infrastructure Manager
(Theme E 30)

The aim of this paper is to analyze the present practice of one organization's life-cycle considerations of products, with the goal of identifying opportunities, obstacles and improvement potential, bearing in mind the environmental pressures from these products. This has been done through an interview study of key persons in the material supply process of the Swedish National Railway Adminstration. The findings suggests that more specific environmental legislation on global environmental issues, such as resource use leading to climate change, would help organizations to translate these issues into organizational guidelines. There seems to be a general demand from purchasers to get more support on setting environmental requirements. In accordance with other studies, this paper’s results indicate that when environmental requirements on life-cycle environmental issues are presented, they tend to be rather vague and not formalized enough, which leads to their being ignored or down-played by the suppliers.

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Environmental Impact of Consumers' Behavior Due to Income, Time Use, and Price Changes: Consumption “Technologies” and the Waste Input-Output Model **(Theme A 14)**

A new analytical model of environmental loads induced by consumption will be introduced. The model also takes account of price changes of consumed products. The model consists of two components: one is the hybrid LCA tool termed the waste input-output (WIO) model (Nakamura and Kondo, 2002, J Ind. Ecol) and the other is one of the economics models describing consumer behavior. By the WIO model, the environmental loads due to consumption can be evaluated for each product in the similar manner as by the conventional input-output model as in LCA. In addition, these environmental loads are related to the upstream of the 3 stages of consumption (purchase, use, and disposal). In the consumer model, meanwhile, given prices, income, and time, the consumers are assumed to choose their activity levels of consumption “technologies” which maximize their utility. A consumption “technology” is expressed as a set of products and time necessary to achieve some purpose, such as eating and transportation. When consumers change their consumption patterns in consideration of environmental problems, the environmental load induced by their own consumption also vary simultaneously. Furthermore, change of the amount of consumption of each product also affects the relation between supply and demand of these products, and then, price changes of the products follow. These price changes possibly affect the people’s consumption patterns even if their income remains unchanged. By integrating the consumer model and the cost and price counterpart of the WIO model (Nakamura and Kondo 2006, Ecol. Econ), we can deal with the feedback noted above. In addition, this model will explain a part of the so-called “economy-wide rebound effects,” as well as both time and income rebound effects.

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Exergy Analysis Applied to the Collection of Used Cooking Oil (UCO) for Biodiesel Production
(Theme B 18)

Used cooking oil (UCO) is yellow grease generated daily during food preparation by food companies and individuals. UCO can be reused in several ways to close the cycle; a) as a fuel for electricity generation in incinerators, b) as grease in the oleochemical industry and c) as a cheaper alternative feedstock to virgin vegetable oils, such as soya or rapeseed oils, for biodiesel production. Reusing UCO not only reduces domestic waste but also minimizes water and soil pollution. Moreover, biodiesel production from UCO is an attractive approach for obtaining fuel transport without reducing the land use required for food crop production and biodiversity. In addition, its production minimises the environmental impact of greenhouse gas and pollutants emissions, such as CO and SO2 thus improving the quality of air, and reduces the dependency upon non-renewable energies. This study evaluates the UCO management system presently in Catalonia, by applying a material and exergy analysis to determine the system efficiency, environmental impacts and possible improvements. Based on these findings, the study further proposes how an improved UCO collection system could end up exploiting the full UCO potential of this region and developing a more sustainable transportation future.

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Material Flow of E-Waste in Asia (Theme A 2)

Rapid economic growth in Asia and increasing transboundary movement of secondary resources will increasingly require both 3R endeavors (reduce, reuse, recycle) in each country and appropriate control of international material cycles. Recently, electrical and electronic waste (hereafter E-waste) has become an important target in managing domestic and international material cycles from the viewpoint of environmental preservation and resource utilization. In order to understand the current status of E-waste issues in the context of international material cycles and to discuss the future tasks required to achieve 3R in each region, we organized the NIES Workshop on E-waste in 2004 and 2005. In this paper, we discuss the current information of material flow and environmental impact of E-waste in Asia, based on the presentation at workshops and our field study. Most Asian countries are increasingly generating E-waste because of their rapid economic growth. Most countries have few reliable data on E-waste generation. The generation data can be primarily estimated with sales data from each country and material flow models, as well as trade flows. Regarding material flow models, simple or distribution delay model is usually used in most Asian countries. Concerning international trade flows, it is not easy to estimate the export or import amount of secondhand electrical and electronic products for reuse. One probable methodology is to estimate the export from total generation and domestic recycling/disposal. Another estimation is to identify secondhand appliances from brand-new ones in the trade statistics, utilizing quantity and monetary value data. For importing countries, available data is rather limited. Material flow will be basic information for controlling the transboundary movement and induced environmental impact. Further inventory survey of E-waste based on the common procedure will be planned for several countries.

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Sustainable Development and Environmental Decision-making - Innovative Tool for Environmental Decision making in Multistakeholder Contexts **(Theme D 27)**

Integrating environmental sustainability into development has received increasing importance in the past decade among the development community. Incorporating environmentally responsible decision making into the development process is recognized as a challenge as it has to consider interests and priorities in a complex multi-stakeholder development process. Stakeholders from different disciplines should be able to recognize and include the life cycle implications of the decision choices. In a multi-stakeholder context with different interests and priorities, decision making methods are required to reduce transaction costs and provide information for collective decision making for developing sustainable strategies. Based on case studies in post-tsunami redevelopment in Sri Lanka, this paper addresses the use of an expert-based tool like LCA in multi-stakeholder decision making process. The case studies demonstrate a framework for incorporating stakeholder and expert knowledge in a participatory multi-stakeholder decision making process in order to include environmental aspects, together with concerns for economic, social, and cultural aspects that are integrated elements of sustainable development. The framework is an innovative instrument and enables stakeholders to explore and define their environmental quality goals and critical impact areas, and subsequently evaluate proposed scenarios with targets for environmentally relevant outcomes. This promotes a better understanding of the linkages between activities and environmental goals. Decision-making with a defined level of environmental quality is the foundation for discussing sustainable practices within a given scale. In addition, the process reveals differences in the assessments of experts vs. non-experts. These differences can then be negotiated and integrated into the decision-making process. When using this LCA-based tool, the stakeholders assume the central role in environmental decision-making.

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Measurement of Eco-Efficiency in Pulp and Paper Factory, a Case Study of Pulp and Paper Industry, Myanmar **(Theme A 12)**

Abstract Current situation of industry and business sectors in Myanmar has been threatened to natural resources because of unsustainable use and development activities. Therefore, it is emergently require concept for stake-holder and government to measure the level of eco-efficiency for each industry and business sector. In this research the eco-efficiency of pulp and paper industry in Myanmar was measured by using the key indicators such as raw material consumption, energy usage, total waste output and water consumption indicators for the pulp and paper production process. This study had been carried out by using quantitative methods for data analysis of the eco-efficiency level of pulp and paper production factory from 2001to 2006. The aims of this research attempted to realize the characteristic and nature of the pulp and paper industry in Myanmar and to evaluate the eco-efficiency of pulp and paper production process. Moreover it could identify possible means to conserve material, energy and water of pulp and paper industry. According to the collected data and results, it can measure and compare the environmental and sustainability level of this factory by using the increase or decrease of eco-efficiency ratio for each financial year. Further on, the analysis determines how to make a sound eco-efficiency comparison between those different fiscal year periods, meaning that to find out the way for reducing the waste as well as the intensity of energy and natural resources in future. The research helps with anticipated results that are believed to be significant in providing feedback to the managers, policy makers and stakeholders.

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Environmental Assessment of Magnesium Component Supply Chain in Automotive Industry
(Theme F 33)

The development of magnesium applications for automotive industries has received significant attention due to its light-weighting and consequent potential to reduce fuel consumption and greenhouse gas (GHG) emissions at the use stage of cars. However, this apparent reduction may be off set by the higher GHG emissions in the manufacture of magnesium components compared to conventional materials, such as steel, aluminium or plastic equivalents. In order to determine the actual environmental advantage or otherwise of magnesium components requires a lifecycle assessment of its impact along the entire component supply chain, from ingot production, casting, use and final disposal and recycling. This paper reports on such an assessment for manufacturing an instrument panel assembly (IP) using magnesium for the main cross car beam. Two main sources of primary magnesium are considered: China (the dominant supplier) and North America. In fact, the GHG impact of magnesium drastically differs between these sources mainly due to the use of one or the other energy source (such as Hydro vs Coal) and materials. The impact of substituting magnesium in IP is compared with some of the current materials, viz. steel and plastic, and newly emerging bio-plastics. This comparison considers a number scenarios including greater recycling of magnesium as a low-impact source and emerging GHG reducing manufacturing technologies. Impediments for improving magnesium recycling are also discussed.

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Barcodes and RFID for Product Lifecycle Management (Theme F 34)

The UPC barcode, introduced thirty years ago, has provided a foundation for significant efficiency gains in product supply chains. This presentation explores the potential for analagous efficiency gains for product recycling, remanufacture, and reuse, through extension of either barcode or radio frequency identification (RFID) for use during the entire product lifecycle. Estimates of the costs, benefits, and technical limitations of a range of applications are provided. The applications considered include RFID tags for curbside waste bins and recycling bins, RFID tags on electronics products, and UPC-type barcodes for product identification for returns management, recycling, and remanufacture.

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A Global Regionalised Environmentally Extended Input-Output Database with a Focus on the EU25 **(Theme A 6)**

This paper seeks to present and receive feedback on the strategy of an EU –funded Integrated Project of various million Euros: EXIOPOL ("A New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis"). This particularly with regard to its part on environmentally extended input output analysis. The project consists of 37 institutes, is lead by FEEM and TNO, and will run between 2006 and 2010. The project has three principal objectives: (a) synthesise and develop further estimates of the external costs of key environmental impacts for Europe; (b) set up an environmentally extended (EE) Input-Output (I-O) framework for the EU-25 in a global context which as many of these estimates as possible are included, allowing the estimation of environmental impacts (expressed as LCA themes, material requirement indicators, ecological footprints and external costs) of different economic sector activities, final consumption activities and resource consumption for countries in the EU; (c) apply the results of the external cost estimates and EE I-O analysis for the analysis of policy questions of importance, as well as for the evaluation of the value and impact of past research on external costs on policy-making in the EU. The EE I-O tool, particularly when linked with dynamic models, will be an extremely powerful support for a great variety of EU environmental and general economic policies. It will allow for analysis, monitoring and improvement assessment of issues such as the total environmental impacts and external costs per industry sector, per final consumption activity, per final product group, related to imports to and exports from the EU25 and per resource used. By splitting up the total consumption into consumption patterns of different target groups, analysis of the life cycle impacts and external costs per target group, life style pattern, etc. becomes possible. The tool will allow for a structural path analysis and contribution analysis (i.e. which sectors or processes contribute to what extent to impacts or external costs related to products or resources used, and if these processes are located in the EU or are related to imports). To date,

the EU's Commission's services such as EEA, Eurostat or DG JRC IPTS have not yet been in the position to develop an integrated IO table for the EU, let alone one that integrates environmental extensions and external costs. It is an explicit goal of the project that the tool should be handed over for structural maintenance and use to one of the relevant Commission's services.

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Governing the Change to Sustainable Consumption and Production (Theme A 14)

SCORE! (Sustainable Consumption Research Exchanges) is an EU-funded network project that supports the UN's 10 Year Framework of Programs on Sustainable Consumption and Production (SCP). It runs between 2005 and 2008, consists of 28 institutions, and aims to involve and structure a larger community of a few hundred professionals in this field, in the EU and beyond. The SCORE! philosophy therefore assumed that sustainable consumption and production patterns can only be realized if experts that understand business development, (sustainable) solution design, consumer behaviour and system innovation policy work together in shaping. New sustainable solutions are often seen as a key for changing production and consumption patterns – calling for a clear role of the design community in this process (Charter and Tischner, 2001; Manzini et al., 2005). Yet, such solutions will only be implemented when consumers accept and businesses can profitably produce them – calling for a clear role ofr experts with a business management background, and consumer scientists, who understand under which conditions consumers can be a driver for change. And last but not least, expertise is needed that understands innovation from a systemic perspective, particularly since many sustainability problems seem to be unsolvable by actors in the production-consumption value chain in an existing market (Elzen et al. 2004; Tukker and Tischner, 2006a). The first phase of the SCORE project will end in September 2006 with a comprehensive review of governance approaches for SCP from these four perspectives and (as far as possible) an integration of these perspectives. The paper will summarize in essence this project result (a book manuscript), which combines the insights of a major project workshop organized with EEA in Copenhagen. The result to be presented will be a state of the art with regard to governance approach for SCP governance, including a short list of do's and don'ts for policy makers.

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Accounting for Water: Strategic Decision Support for Sustainable Water Futures. (Theme D 27)

The Victorian Water Account is an accounting and simulation tool for water supply, use and consumption in the State of Victoria, Australia. The account is a novel hybrid of systems dynamics and basic accounting: it tracks the stocks and flows of physical quantities relating to the water system but it is also part of, and informed by, an integrated framework of similar calculators (The Victorian Region Stocks and Flows Framework - VRSFF) for simulating long-term interactions between the many other sectors of the physical economy. Through the VRSFF, the Water Account is linked to the Australian National Framework. This allows multiscale scenarios of population, land use, energy and water futures to influence catchment level outputs such as the operational and embodied consumption of water, flow in river networks and the energy cost of transporting and treating water. The simulation time of 100 years permits the observation of long range indirect influences and the impact of slow moving variables to become apparent. Results presented will demonstrate such effects. Of particular interest is the major city and user of urban water in Victoria, the City of Melbourne. While water use by agriculture may be many times that used in the urban context, it is the essential nature of urban water for habitation that makes it a current priority in Australian cities. To confront this issue the Water Account, in connection with VRSFF, has the facility to explore many alternative scenarios of urban water sourcing, treating, delivery and end use. There is also the potential to refine the account to explore such questions as the consequences for water supply and quality concurent with peri-urban land use transitions. The Water Account has been developed in coordination with the policies and aspirations of the Victorian State Government who are natural end-users of this tool.

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Collaborative Industry Research to Develop Inorganic By-Product, Water, and Energy Synergies: Experiences and Lessons from Kwinana **(Theme E 29)**

The Kwinana Industrial Area (in Western Australia) is home to a diverse range of mineral processing and other heavy industries. Regional synergies have truly taken off since the late 1980s, providing economic, environmental and social benefits, and making Kwinana a world leading example of regional synergy development. The Centre for Sustainable Resource Processing (CSRP) launched the Kwinana Synergies Project in 2004 to provide practical support to the Kwinana industries for the identification and further development of regional synergies. Significant progress has been made so far to further develop promising one-on-one company synergies (e.g. industrial effluents, inorganic and organic by-products). The research findings to date confirm that there is no “one-size-fits-all” approach for synergy development. The type and level of assistance depends entirely on the specific research needs of the involved industries (e.g. facilitation, evaluation of processing technologies, business case evaluations). One of the future challenges for the Kwinana Synergies Project is to facilitate the implementation of one or more of the identified synergy opportunities. Strong commitment from industry, Kwinana Industries Council (KIC, local industries representative body), and the CSRP will assist in achieving this goal. The Kwinana Synergies Project also contributes to the development of collective strategies on the recovery and reuse of inorganic by-products, water, and energy. These efforts have a more long-term and strategic focus, and include most major industries and the Kwinana Industries Council. In developing these strategies detailed assessments of targeted industry data on inorganic by-products (e.g. bauxite residue, gypsum), water (e.g. treated effluents, boiler blowdown), and energy (e.g. flue gases, hot water) have been conducted and analysed in opportunity identification workshops. The conference presentation will give an overview of the experiences and lessons learnt from applied approaches in developing one-on-one company synergies and

collective Kwinana strategies, including the challenges and opportunities for the way forward.

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Eco-Efficiency and Innovation for Primary Minerals and Metals Production (Theme A 12)

Sustainability's imperative of economic development in tandem with social advancement and environmental protection is widely accepted, but much debate remains about its practical implications for the products, materials and technologies of the future. The challenge remains to turn sustainability into a value-adding framework for innovation in processes, technologies, business models and management systems in specific industry sectors, for which Eco-Efficiency (EE) can provide a starting point. This paper discusses how the primary minerals and metals industries can do so, illustrated with Australian examples. This paper provides both sustainability and operational perspectives on the application of EE in the primary minerals and metals industries. The sustainability perspective is first clarified using a hierarchy of sustainability principles, from the fundamentals of ecological systems to operational practices and metrics for businesses, which justifies a focus on EE at the firm level. Earlier attempts to define EE and related concepts in the context of primary minerals and metals production are briefly reviewed, leading to a novel operational EE framework. This connects five 'prevention practices' (process design; input substitution; plant improvement; good housekeeping; and reuse and recycling) with five 'resource productivity themes' (resource efficiency; energy use and greenhouse gas emissions; water use and impacts; control of minor elements and toxics; and by-product creation). EE methods are then outlined as they apply to continuous improvement of existing operations and in the realisation of major projects. It is concluded that EE and innovation are important milestones on the sustainable development journey of the primary minerals and metals industry.

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Ideation in Industrial Ecology: Innovation for and through Sustainability (Theme E 31)

Despite the many industrial ecology examples in businesses, these are still leading and not yet common practice. A very plausible explanation is that organisations find it difficult to innovate, as this depends on thinking about 'how they can do differently what they are doing well'. The term ideation is introduced for the process of getting an idea (the creativity) and its subsequent development, evaluation and implementation in a product or process (the development and/or engineering). Randomised ideation is widely supported in business and engineering, and similarly in industrial ecology, through brainstorming or the like. It is assumed that the more ideas are being generated, the more likely that one will surface that is truly innovative. There is however hardly any evidence that innovative ideas do surface, due to short term and entrenched thinking and interpersonal issues. An alternative approach is replicated ideation, which takes the form of replication of environmental features, to do the same, or preferably slightly better than, a benchmark environmental product or process. Despite its appeal, this runs the risk of incorporating environmental features that have limited impact on the product's total environmental impact. Systemic ideation structures the ideation process by incorporating patterns derived from successful product developments in the past. It systematises the inventiveness and creativity, to arrive at break through product concepts that may then be developed into functional products. These ideation approaches will be illustrated with prominent industrial ecology tools: productivity themes (for semi-randomised ideation), eco-design strategies (for replicated ideation) and creativity templates (for systemic ideation). Practical examples of eco-innovative products and processes, illustrate that sustainability is good for innovation and vice versa, innovation good for sustainability.

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Laws of the Technosphere **(Theme A 3)**

The biosphere-technosphere metaphor is a powerful idea, residing at the heart of the Industrial Ecology field. Over the years, this metaphor has led to some useful ideas on how to arrange our production systems. Also, some have pointed out that the analogy does not always lead us in a useful direction. The question is, should we see this metaphor as a vaguely inspiring idea or is it possible to draw real consequences out of it? If so, we should be able to detect technospheric laws, comparable to the laws of nature. This presentation speculates on Laws of the Technosphere. Some of the laws of nature are applicable in the technosphere as well. Economic laws also have their physical representation in the technosphere. Combining them could lead to laws representing the behaviour of the complex system that is the technosphere, operating at the interface of society and nature.

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Sustainable Resource Use: How to Measure Progress? **(Theme A 13)**

Policies for a sustainable resource use are formulated at the national level. A main question is, how can we measure progress on the road to sustainability? Decoupling and dematerialisation indicators are being defined. There are two major challenges in defining such indicators: (1) integrating all types of environmental impacts associated with resource use into one measure, and (2) accounting for the cradle and grave of the chains of resource use that takes place in other countries. This presentation will give the state of the debate around such indicators. Some propositions will be made to deal with these issues, and some results of the application of the proposed approach will be given.

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How the Enterprise Ownership Affects Industrial Symbiosis: Cases in China (Theme C 20)

Being wastes or by-products exchanging behaviors among enterprises, industrial symbiosis is affected by many factors, including the ownership. China, the largest transformation country, provides good cases studies for this research. In this paper, Yangzhou and Yixing city, both in Jiangsu province east China, are taken as cases. Three parts are included in this paper. The first part provides the background of industrial symbiosis, including economic, resources and environmental aspects. The second describes the status of industrial symbiosis, past and present, and their evolution process. In the third part, we provide a framework to explain why happened like that. Here, the comparative study methodology is adopted. More details, we try to separate the institutional issue from other issues like economic, environmental and technical aspects. Based on our primary work, several patterns of industrial symbiotic relationship are identified, and how the ownership affects the industrial symbiosis is discussed.

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Characteristics and Demographics of the International Environmental Impacts of American Household Consumption **(Theme A 14)**

One of the most important and well-studied aspects of sustainable consumption (SC) has been detailing the energy and emissions requirements to meet household demand of goods and services. However, despite significant recent work, relatively few studies in the SC literature have considered the effects of international trade and transport in the calculation of household environmental footprint. Globalization of product supply chains has made it imperative for researchers to consider international differences in the energy and emissions requirements of goods made in the developed and developing worlds. This research attempts to discover the linkages between American household consumption and its associated international climate and air pollution impacts through the use of a hybrid life-cycle assessment model of the United States and several of its trading partners (Canada, Mexico, China, Japan, Korea, the UK, and Germany). Combining data from many sources, including detailed micro-scale household consumption surveys, international trade data, input-output models, and energy and emissions data from each country, this work shows the importance of global supply chains for the determination of the consumers' environmental intensities. Indeed, calculations show that between 3% and 25% and between 29% and 50% of a household's CO_2 and SO_2 footprints, respectively, occur outside of the US. The analysis is carried out on two different levels: the individual household and the nation as a whole. By classifying individual households by available sociodemographic information supplied in the consumption survey data, several conclusions are drawn regarding the importance of household size, income/expenditure, and several other sociodemographic variables in predicting and scaling household environmental culpability. Uncertainties in the modeling work are investigated and quantified when possible. Finally, the policy relevance of the work is discussed, in relation to international climate policy.

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Industrial Ecology: Hard Science or Gentle Inspiration (Theme D 24)

The emergent discipline of industrial ecology is composed of, and drawn from, two essentially opposing philosophical perspectives and, as with the great intra-disciplinary battles of the past the threat of epistemological schism looms. For some, industrial ecology is an empirical, quantitative and fundamentally positivist science whose architectural substance is defined by the tools and techniques employed; it is about objectively measured truth derived from the analysis of a given reality. For others, in contrast, industrial ecology is about discourse, and to this extent the metaphor that lies at the heart of the discipline is not a technique or a methodology as such, but an inspirational insight: literally a different way of looking at the world. This paper explores the dualism that lies within industrial ecology as the discipline has emerged. It seeks to expose the strengths and weaknesses of both positions; from the reductionism that pervades the hard industrial ecology approach to the naive normative idealism of the conceptual and qualitative approach. In so doing, the purpose is not to set one faction against another, nor to promote one truth as more self-evident than another. Rather, the paper concludes that industrial ecology can be neither purely hard science nor gentle inspiration. With the need for change becoming more compelling by the day, this paper uses illustrations from the automotive industry to argue that while industrial ecology as positivist science is crucial to helping understand the dimensions of the problems we face, as a normative metaphor it can also be used to generate visionary solutions and insights.

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Technology, Risk, and Sustainable Development
(Theme A 13)

Technology has become one of the most important factors for economic development. The question can be raised how important is technology really for achieving a sustainable development on a regional and global scale. If we look at the UN millennium goals we will discuss the role of technology in achieving these goals. Another important factor is technology and risk. What kind of new risks will be introduced with new technologies and how can we assess them from a sustainability point of view. The history shows us that the delay of revealing risks with new technologies could be as long as 50 years and then the damage to environment could be severe. At the same time there is a constant stream of unsystematic alarms from media around new technologies. In this paper we will try to structure what we actually mean with technology and the importance of technology for economic growth in different sectors in society. Different general principles for risk evaluation of new technologies have been developed and these will be applied to some new technologies e.g. nano technology, energy technologies like nuclear power, gene therapy, ICT, genetically modified (GM) organisms like crop plants. We will also discuss the need for participatory processes in society when introducing new technologies and we will introduce the concept of technological culture and the lack of such a culture is one of the basic problems with technology in our society.

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Uncertainty Analysis and Hybrid Process-Economic LCI **(Theme A 5)**

The task of producing reliable and reproducible calculation of life cycle inventories (LCI) remains a major challenge for the LCA community. LCI results representing the same product or service vary widely depending on data sources and method used. Major differences in results of LCA studies represent a major barrier to its wider societal acceptance as a tool to advise real world decisions. Even for energy use, the parameter for which data sources are presumably most accurate, results of materials based process-sum and economic input-output LCA often differ by a factor of two or more. For emissions of some chemicals, uncertainties in input data could be a factor of 100-1000. Currently, estimation of uncertainty in LCA studies rarely goes beyond sensitivity analysis of input data. There are different kinds of uncertainty (e.g. model, data, aggregation, geographical, temporal) that can be significant and are at least partially tenable to quantitative estimation. Both process-sum and economic input-output LCI methods display potentially large uncertainty, though with different profiles of uncertainty type. Hybrid LCI, the combination of the two methods, presents a way to reduce overall uncertainty, but to be meaningful must be explored in the context of explicit estimation of its benefits. Improved characterization and management of uncertainty in LCI is eminently possible and should be an important priority of the LCA community.

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Efficiency Dilution and Technology Asymptotes: Long-Term Exergy Conversion Trends in Japan
(Theme D 25)

This analysis addresses long-term trends in exergy efficiency in Japan. This measure – also known as second-law efficiency -- captures the degree to which exergy inputs (such as coal) are converted into a useful work (such as electricity or power to move a vehicle). Sectors specifically considered are electricity conversion, transport, steel production and residential space heating. We estimate net efficiencies combining different technologies and services by weighting according to respective shares of exergy consumption in the economy. One result is that the aggregate exergy efficiency of the Japanese economy declined slightly over the last half of the 20th century, reaching a high of around 38% in the late 1970's and falling to around 33% by 1998. The explanation for this is that while individual technologies improved dramatically over the century, less exergy-efficient ones were progressively adopted, yielding a net stabilization or decline. For instance, in the electricity sector, adoption of hydropower was followed by fossil-fired plants and then by nuclear power, each technology being successively less efficient from a 2nd law perspective. The underlying dynamic for these trends is analogous to declining ore grades in the mining sector, with increasing demand for exergy services required the use of successively lower quality exergy resources (e.g. coal vs. falling water). We term this phenomenon efficiency dilution. A second result is that many of the individual technologies studied (such as fossil-fuel power plants and steel production) display logistic curve (or S-curve) type behavior, with very little to no improvement seen the last several decades.

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Planning and Evaluation of Environmental Improvement Effects for Municipal Solid Waste Matter Recycling Scheme **(Theme B 18)**

Population intensive municipal region generates large quantity of wastes which are commonly incinerated and landfilled. With the increasing concern of global warming and unsustainable fossil fuel supply, it is necessary to consider the schemes of energy and material recycling for municipal solid wastes to reduce energy consumption for the process of waste treatment. To promote municipal recycling activities, this paper focuses on a scenario planning and integrated evaluation process of waste recycling policies. MSWM policy scenarios consist of a variation of conversion technologies are developed by clarifying possible collaborations with local recycling-oriented manufacturing and heavy industries, and then quantitative inventory data are surveyed and utilized for scenario simulations. Applications of single technology as well as a combination of multiple technologies are designed for alternative policy scenarios, and environmental impacts of local recycling rate, landfill disposal quantity and CO_2 emission are evaluated. A spatial database of waste emissions and transportation network are developed to determine collection boundaries and transportation distances to treatment or recycling facilities. In this paper, seven scenarios for future waste recycling strategies in Kawasaki City were planned based on optional factors including renovation schedule of incineration plants and waste recycling potential by manufacturing industries. Kawasaki City is high in human activities and accumulates with well-established industries. In 1997, Kawasaki coastal industrial zone was designated as one of the first batch Eco-towns in Japan to promote resource recycling practices in industrial sector. Hypothetical simulations on recycling scenarios targeting municipal household mix papers, waste container & packaging plastics, and food waste from business sectors were performed. Local manufacturing industries including paper, steel and cement manufacturing industries were identified to equip with conversion technologies to accept wastes in the production processes.

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The Practice of the Logo for Ecological Management of Industrial Solid Wastes in Tianjin Economic-Technological Development Area ?TEDA?in China **(Theme C 22)**

In order to promote the progress of reducing, reuse and decontamination of industrial solid wastes according to the principle of 3R(reduce, reuse, recycling), Tianjin Economic-Technological Development Area (TEDA), which is one of the best industrial development areas in china has taken a practice, namely, Establishment of Logo for Ecological Management of Industrial Solid Wastes in TEDA. This paper systemically introduces the contents and operational modes of the Logo system? and summarizes the environmental and social benefit which the companies or factories gain in implementing the logo system in TEDA. In the end, the paper put forwards some suggestions and measures for the other development area waste management in china based on the existing problems in this case study.

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Life Cycle Assessment of Emerging Technologies – Can Thermodynamics Help?
(Theme D 25)

The benefits of LCA are likely to be most significant for emerging technologies and at early stages of decision making. Unfortunately, traditional LCA is best suited for evaluating more mature technologies because it relies on detailed data about emissions throughout the life cycle and their impact. Such data are often not available for emerging technologies such as nanotechnology, green chemistry, and new fuels due to a sheer lack of information or the slow pace of toxicological studies. In contrast, data about material and energy inputs to even emerging technologies is much more readily available. This talk will explore whether LCA based only on input-side data can provide a proxy for life cycle impact. Techniques for input-side LCA that will be considered include those based on mass, energy, industrial cumulative exergy (ICEC) and ecological CEC. Thermodynamics is expected to play a unique role in connecting life cycle inputs with LCA impacts, because all ecological and industrial processes are networks of energy flows. Exergy is the measure of the available energy. If more exergy is consumed in a process, it results in a larger increase in entropy of the surroundings which may translate into a bigger environmental impact. Therefore, life cycle cumulative exergy consumption may be a proxy for life cycle impact. The relationship between input-side LCA metrics and output-side LCA metrics are being explored with the help of a hybrid thermodynamic input-output LCA. Statistical regression and hypothesis testing are being used to determine whether a statistically valid model exists. Preliminary results are promising, but more studies are underway. If validated, the model is expected to be very useful for preliminary screening and evaluation of emerging technologies and at early stages of decision making. As more information about emissions and impact become available, they may be incorporated in the thermodynamic LCA approach.

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Waste Input-Output Analysis OF Advanced Loop-Closing Systems by Combining Established Manufacturing Infrastructure and Innovative Environmental Technologies (Theme A 8)

Various advanced loop-closing systems are promoted by combining the established infrastructure for manufacturing sectors and the recycling-oriented innovative environmentally-friend production technologies. In this paper, Waste Input-Output (WI-O) model, developed by Nakamura and Kondo, were applied to evaluate the material flow and the environmental loads due to technological changes such as scrap melting process in steel industry and biomass utilization technology in cement industry. Input or technological coefficients were set up for each technology and the substitution scenarios based on the material flow analysis. The result of the analysis in steel industry showed that the advanced loop-closing system reduced the amount of natural resource input by 9.2% and improved the resource productivity by 6.15% compared with the conventional recycling system. In the case of cement industry, it was revealed these coal substitution could reduce total carbon dioxide emission by 486 thousand t-C comparing with the standard level in spite of increased energy consumption due to pretreatment of waste. Embodied waste generation was also estimated to reduce by 0.41 Million ton with enhancement of the biomass utilization. We also analyzed nearly half of carbon dioxide reduction by biomass utilization in direct burning production processes with newly developed internally circulated fluidized bed gasification process. Further methodological issues to express these technological coefficients were also discussed.

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An Integrated Framework for Sustainability Assessments of Urban Environments (Theme B 15)

Cities are spatial patterns that persist in time, in which no single constituent remains in place. Urban systems emerge as distinct entities from the complex interactions among social, financial, and cultural attributes, and information, energy, and material stocks and flows that fundamentally operate on a spatial scale. The key intellectual challenge of urban sustainability is a fuller understanding of the integrated dynamic spatial interactions among these components. This understanding, in turn, can inform urban decision makers of the environmental impacts of decisions and actions that are driven by urban needs. We address this challenge by developing a generic agent-based model (ABM) to integrate historical quantitative data on material and energy stocks and flows, and social indicators of quality of life within the Chicago metropolitan area. The ABM is used to explore the effects of land-use, infrastructure and resource management policies on environmental quality. The generic ABM has diverse agents (e.g. residents, firms, and institutions) making choices about location, redevelopment, transportation, and resource consumption and supply. Agents' decisions are affected by their individual attributes, by policy and by landscape characteristics. In turn, agents' behavior affects the landscape and the source from which they extract resources. The resource systems have replenishment rates and flow mechanisms. The parameters values and mechanisms of the model are based on historical data in the Chicago metropolitan region, existing literature and expert knowledge from the various decision-makers that are represented in the model. Interactions between the various components of the integrated model are tested by varying alternatively the behavioral and the biophysical dimensions and examining the effects on the simulations. This integrated framework enables us to make meaningful comparisons among scenarios for large-scale urban systems, directly contributing to decision-making and policy development, and providing the theoretical basis and appropriate tools for advancing the sustainability of urban systems.

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Dynamic Life Cycle Modeling of Pavement Overlay System: Capturing the Impacts of Users, Construction, and Roadway Deterioration **(Theme B 19)**

While pavements are central elements of transportation systems, pavements in the United States are significantly deficient. An estimated 58% of America's urban and rural roadways are in poor, mediocre, or fair condition. Concrete and asphalt are the most common materials used in the construction of pavement system. Both concrete and asphalt pose significant environmental challenges. Production of cement, a key constituent in concrete, accounts for more than 1.6 billion tons of CO_2 over 8% of total CO_2 emissions from all human activities and significant levels of other pollutants, such as particulate matter and sulfur oxides. Asphalt, a petroleum byproduct, is energy intensive and emits high levels of volatile organic compounds (VOC) during construction. Additionally, concrete and asphalt have some physical limitations that contribute to limited durability, which increase pavement failure and maintenance frequency. To improve the sustainability in pavement rehabilitation design a promising alternative material, engineered cementitious composites (ECC), is explored. This study conducts a comparative life cycle assessment (LCA) of an unbonded concrete overlay, a hot mix asphalt (HMA) overlay and an ECC overlay over a 40 year life cycle. A dynamic life cycle model is developed to capture the environmental impacts on material production and distribution, overlay construction and maintenance, construction-related traffic congestion, overlay usage, and end of life management. Because of the physical properties improvement of ECC, results show that the ECC overlay system saves at least 14% of the total life cycle energy consumption and 34% of the greenhouse gas (GHG) emission. The processes contributing the greatest environmental impact are highlighted in life cycle study.

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Mongstad Future Fuel Park – Flexible Options for Producing New Fuels in a Carbon-Constrained World **(Theme F 32)**

The need to reduce the global emissions of CO_2 and the mobile emissions of particulate matter as well as the depletion of oil reserves may lead to significant changes in the types and quality of transportation fuels required and available for the future. Significant changes are likely within the lifetime of investments in refinery and process equipment. The option to produce cleaner fuels with flexible resources is hence of significant value to oil companies. We present an analysis of potential future designs of a Future Fuel Park integrated with or modifying the existing refinery at Mongstad, considering multi-feedstocks and with the same equipment and processes. The analysis is based on a process integration results with rigorous thermodynamic and kinetic models. The different options are evaluated on the basis of the energy, carbon, and hydrogen balances. Different options for handling this CO_2 are included in the analysis. This work will provide new scenarios for the future new and cleaner energy system.

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On Mine Ecological Construction (Theme F 34)

The concept of mine ecological construction is posed in this paper based on the recognition of laws of mining influence on eco-environment, which includes either mine ecological restoration, reclamation after mining or eco-environmental planning and protection before mining. The influences of mining on eco-environment are not wholly negative, also including positive ones. Thus, we can take measures to lessen negative influences and take advantage of positive ones during the whole process of mining in terms of systems engineering. The principles of industrial ecology provide the best guidance for mine ecological construction, and the concept of externalities in economics provide the clue to account the cost of environment for mining activities. Two examples are shown in this paper, one of which shows the effectiveness of mine ecological protection at Shendong coal mining area in the boundary of Shan'xi and Inner Mongolia and the other shows the effectiveness of ecological reclamation after mining at Xuzhou coal mining area being of typical mine eco-environmental features of East China. It has been proved that mine ecological construction is an urgent issue, which should be solved and we must focus on theoretical innovation and technical integration to guide the practice of mine ecological construction.

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Study on Building Shanghai into a Circular Economy Oriented Sustainable City (Theme C 21)

Since 1998, Shanghai has started to pay attention to the development of circular economy in countries like Germany and Japan, and to introduce the conception of circular economy to Shanghai's city development scheme. Currently, Shanghai is further integrating the circular economy into its strategic objective of becoming a sustainable cosmopolitan city. The paper puts forward some ideas concerning why and how Shanghai should be constructed into a circular economy oriented city, and discusses some general circular economy problems both theoretically and practically.